US007465366B2

(12) **United States Patent**
Provost et al.

(10) **Patent No.: US 7,465,366 B2**
(45) **Date of Patent: *Dec. 16, 2008**

(54) **NEEDLING LOOPS INTO CARRIER SHEETS**

(75) Inventors: **George A. Provost**, Litchfield, NH (US); **James R. Barker**, Francestown, NH (US); **Howard A. Kingsford**, Amherst, NH (US)

(73) Assignee: **Velero Industries B.V.**, Curcao, Netherlands Antilles

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 473 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **11/104,166**

(22) Filed: **Apr. 8, 2005**

(65) **Prior Publication Data**

US 2005/0196581 A1 Sep. 8, 2005

Related U.S. Application Data

(63) Continuation-in-part of application No. 10/728,138, filed on Dec. 3, 2003, now Pat. No. 7,156,937.

(60) Provisional application No. 60/430,731, filed on Dec. 3, 2002.

(51) **Int. Cl.**
B32B 37/00 (2006.01)

(52) **U.S. Cl.** **156/148**; 156/72

(58) **Field of Classification Search** 156/148, 156/72

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,706,324 A * 4/1955 Cogovan 428/89
3,348,992 A 10/1967 Cochran, II
3,408,417 A 10/1968 Sogawa et al.
3,535,178 A 10/1970 Parlin et al.
3,674,618 A 7/1972 Spann
3,704,191 A 11/1972 Buresh et al.
3,819,462 A 6/1974 Starr et al.
3,950,587 A 4/1976 Colijn et al.
4,001,472 A 1/1977 Thomas et al.
4,010,302 A * 3/1977 Anderson et al. 428/95

(Continued)

FOREIGN PATENT DOCUMENTS

EP 0 211 564 2/1992

(Continued)

OTHER PUBLICATIONS

Dilo Group, "Market Leadership in Nonwovens Technology", Pakistan Textile Journal, date unknown (2 pages).

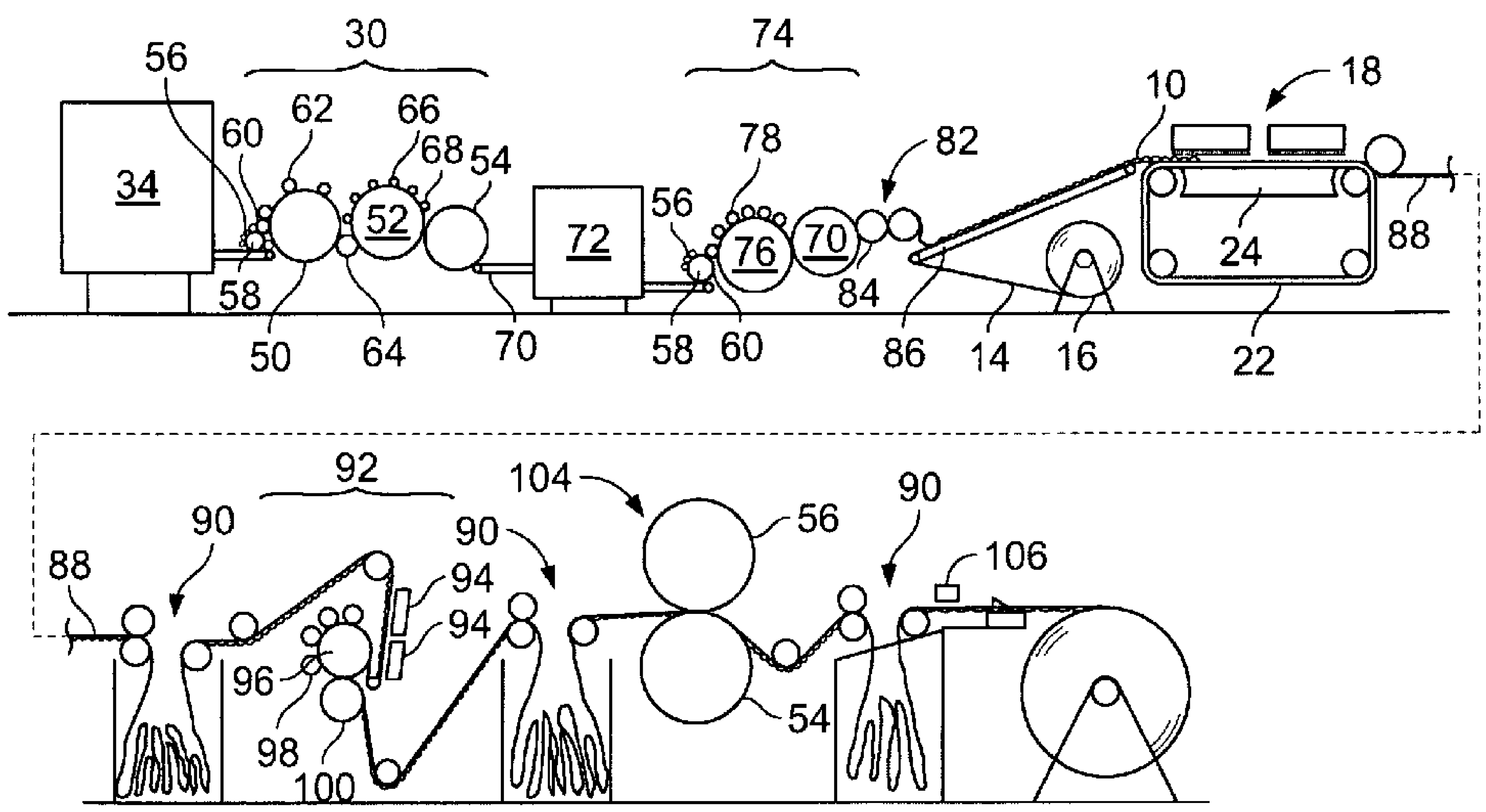
(Continued)

Primary Examiner—Jeff H Aftergut
(74) *Attorney, Agent, or Firm*—Fish & Richardson P.C.

(57) **ABSTRACT**

A sheet-form loop product includes a flexible paper substrate and a layer of staple fibers disposed on a first side of the substrate, exposed loops of the fibers extending from holes through the substrate to a second side of the substrate, with bases of the loops being anchored on the first side of the substrate. The loops can be fastening loops. The product is formed by needling the fibers through the paper and then bonding the fibers. Examples include loop fastener materials, towels, abrasive scrubbing pads and sanding materials.

9 Claims, 11 Drawing Sheets



U.S. PATENT DOCUMENTS

4,035,533 A 7/1977 Chambley
4,116,892 A 9/1978 Schwarz
4,131,704 A 12/1978 Erickson et al.
4,154,889 A 5/1979 Platt
4,192,086 A 3/1980 Sichak
4,223,059 A 9/1980 Schwarz
4,258,094 A 3/1981 Benedyk
4,258,097 A 3/1981 Benedyk
4,295,251 A 10/1981 Tatham et al.
4,320,167 A 3/1982 Wishman
4,324,824 A * 4/1982 Narens et al. 428/92
4,342,802 A 8/1982 Pickens, Jr. et al.
4,377,889 A 3/1983 Tatham et al.
4,379,189 A 4/1983 Platt
4,389,442 A 6/1983 Pickens, Jr. et al.
4,389,443 A 6/1983 Thomas et al.
4,391,866 A 7/1983 Pickens, Jr. et al.
4,418,104 A 11/1983 Kiyomura et al.
4,439,476 A * 3/1984 Guild 428/96
4,446,189 A 5/1984 Romanek
4,451,314 A 5/1984 Knoke et al.
4,490,425 A 12/1984 Knoke et al.
4,521,472 A 6/1985 Gold
4,536,439 A 8/1985 Forsten
4,600,605 A 7/1986 Nakai et al.
4,600,618 A 7/1986 Raychok, Jr. et al.
4,609,581 A 9/1986 Ott
4,645,699 A 2/1987 Neveu
4,654,246 A 3/1987 Provost et al.
4,750,443 A 6/1988 Blaustein et al.
4,770,917 A 9/1988 Tochacek et al.
4,931,343 A 6/1990 Becker et al.
5,032,122 A 7/1991 Noel et al.
5,080,951 A 1/1992 Guthrie 428/85
5,144,730 A 9/1992 Dilo
5,216,790 A 6/1993 Eschenbach
5,254,194 A 10/1993 Ott et al.
5,256,231 A 10/1993 Gorman et al.
5,326,612 A 7/1994 Goulait
5,380,580 A 1/1995 Rogers et al.
5,391,424 A 2/1995 Kolzer
5,407,439 A 4/1995 Goulait
5,407,722 A 4/1995 Peake, III et al.
5,447,590 A 9/1995 Gilpatrick
5,449,530 A 9/1995 Peake, III et al.
5,470,417 A 11/1995 Goulait
5,500,268 A 3/1996 Billarant
5,518,795 A 5/1996 Kennedy et al.
5,547,531 A 8/1996 Allen et al.
5,571,097 A 11/1996 Seth
5,599,601 A 2/1997 Polski et al.
5,603,708 A 2/1997 Seth
5,605,729 A 2/1997 Mody et al.
5,611,789 A 3/1997 Seth
5,611,791 A 3/1997 Gorman et al.
5,614,232 A 3/1997 Torigoe et al.
5,614,281 A 3/1997 Jackson et al.
5,615,460 A 4/1997 Weirich et al.
5,616,155 A 4/1997 Kronzer
5,616,394 A 4/1997 Gorman et al.
5,622,578 A 4/1997 Thomas
5,630,896 A 5/1997 Corbin et al.
5,643,397 A 7/1997 Gorman et al.
5,654,070 A 8/1997 Billarant
5,660,911 A 8/1997 Tesch
5,669,900 A 9/1997 Bullwinkel et al. 604/391
5,685,756 A 11/1997 Noda
5,692,949 A 12/1997 Sheffield et al.
5,707,707 A 1/1998 Burnes et al.
5,707,906 A 1/1998 Eschenbach
5,759,926 A 6/1998 Pike et al.
5,763,041 A 6/1998 Leak et al.
5,773,120 A 6/1998 Deka et al.
5,786,060 A 7/1998 Takahashi et al.
5,814,390 A 9/1998 Stokes et al.
5,843,057 A 12/1998 McCormack
5,858,515 A 1/1999 Stokes et al.
5,866,222 A 2/1999 Seth et al.
5,888,607 A 3/1999 Seth et al.
5,891,547 A 4/1999 Lawless
5,904,793 A 5/1999 Gorman et al.
5,931,823 A 8/1999 Stokes et al.
5,945,215 A 8/1999 Bersted et al.
5,962,102 A 10/1999 Sheffield et al.
5,962,112 A 10/1999 Haynes et al.
5,964,742 A 10/1999 McCormack et al.
5,997,981 A 12/1999 McCormack et al.
6,051,094 A 4/2000 Melbye et al.
6,086,984 A 7/2000 DiMaggio, Jr. et al.
6,093,665 A 7/2000 Sayovitz et al.
6,129,879 A 10/2000 Bersted et al.
6,129,964 A 10/2000 Seth
6,162,522 A 12/2000 Deka et al.
6,192,556 B1 2/2001 Kikko et al.
6,195,850 B1 3/2001 Melbye et al.
6,265,053 B1 7/2001 Kronzer et al.
6,329,016 B1 12/2001 Shepard et al.
6,342,285 B1 1/2002 Shepard et al.
6,355,759 B1 3/2002 Sherman et al.
6,368,444 B1 4/2002 Jameson et al.
6,410,138 B2 6/2002 Mleziva et al.
6,454,989 B1 9/2002 Neely et al.
6,489,004 B1 12/2002 Martin et al.
6,537,935 B1 3/2003 Seth et al.
6,598,276 B2 7/2003 Shepard et al.
6,638,611 B2 10/2003 Seth
6,642,160 B1 11/2003 Takahashi
6,642,429 B1 11/2003 Carter et al.
6,645,611 B2 11/2003 Seth
6,660,202 B2 12/2003 Shepard et al.
6,686,303 B1 2/2004 Haynes et al.
6,703,086 B2 3/2004 Kronzer et al.
6,709,996 B2 3/2004 Mleziva et al.
6,716,511 B2 4/2004 Bersted et al.
6,740,385 B2 5/2004 Gardner et al.
6,756,327 B2 6/2004 Martin
6,783,834 B2 8/2004 Shepard et al.
6,849,142 B1 2/2005 Goulait
6,869,659 B2 3/2005 Shepard et al.
7,156,937 B2 * 1/2007 Provost et al. 156/148
7,276,642 B2 10/2007 Belau
7,282,251 B2 10/2007 Provost et al.
2001/0051253 A1 12/2001 Tai et al. 428/167
2004/0020579 A1 2/2004 Durrance et al.
2004/0072491 A1 4/2004 Gillette et al.
2004/0131820 A1 7/2004 Turner
2004/0157036 A1 * 8/2004 Provost et al. 428/85
2005/0196580 A1 9/2005 Provost et al.
2005/0196583 A1 9/2005 Provost et al. 428/95
2005/0208259 A1 9/2005 Provost et al.
2005/0217092 A1 10/2005 Barker et al.
2006/0105664 A1 5/2006 Zafiroglu
2006/0183389 A1 8/2006 Zafiroglu
2006/0225258 A1 10/2006 Barker et al.
2007/0178273 A1 8/2007 Provost et al.
2008/0113152 A1 5/2008 Provost et al.

FOREIGN PATENT DOCUMENTS

EP 0 325 473 3/1993
EP 0 598 085 7/1997
EP 0 597 075 4/1998
EP 0 882 828 A1 12/1998
EP 0 937 420 8/1999

EP	0 726 977			6/2000
EP	0 861 137			1/2002
EP	1 279 348	A1		1/2003
EP	1 156 767			10/2004
EP	1 113 099			3/2006
GB	1228431	A	*	4/1969
JP	6-33359			2/1994
JP	06-123061			5/1994
JP	7-171011			7/1995
JP	08-27657			1/1996
JP	09003755			1/1997
JP	09-195155			7/1997
JP	10-146207			6/1998
JP	10-151005			6/1998
JP	2971332			11/1999
JP	2001-212			1/2001
JP	2001-8713			1/2001
JP	3134709			2/2001
JP	2001-207369			8/2001
JP	2001-514346			9/2001
JP	2002-10807			1/2002
JP	2003-265207			9/2003
JP	2004-194730			7/2004
JP	3855084			12/2006
JP	3877842			2/2007
WO	WO98/33410			8/1998
WO	WO99/11452			3/1999
WO	WO01/80680			1/2001
WO	WO 02/100207	A2		12/2002
WO	WO 02/100207	A3		12/2002
WO	WO03/051251			6/2003
WO	WO2004/019305			3/2004
WO	WO2004/049853			6/2004
WO	WO2004/058118			7/2004
WO	WO2004/058497			7/2004
WO	WO2004/059061			7/2004
WO	WO2004/059117			7/2004

OTHER PUBLICATIONS

Dilo, "Engineering Excellence in Needle Looms!", Hyperpunch—The Solution for Fine and Quality Fleeces, Synthetic Leather, Spunbondeds, Papermachine Felts!, date unknown (2 pages).

Purdy, Terry, Dilo Inc., Needle Punching Benefits from Elliptical Needle Paths, date unknown (13 pages).

U.S. Appl. No. 12/133,769, filed Jun. 5, 2008, Barker et al.

U.S. Appl. No. 12/133,945, filed Jun. 5, 2008, Provost et al.

* cited by examiner

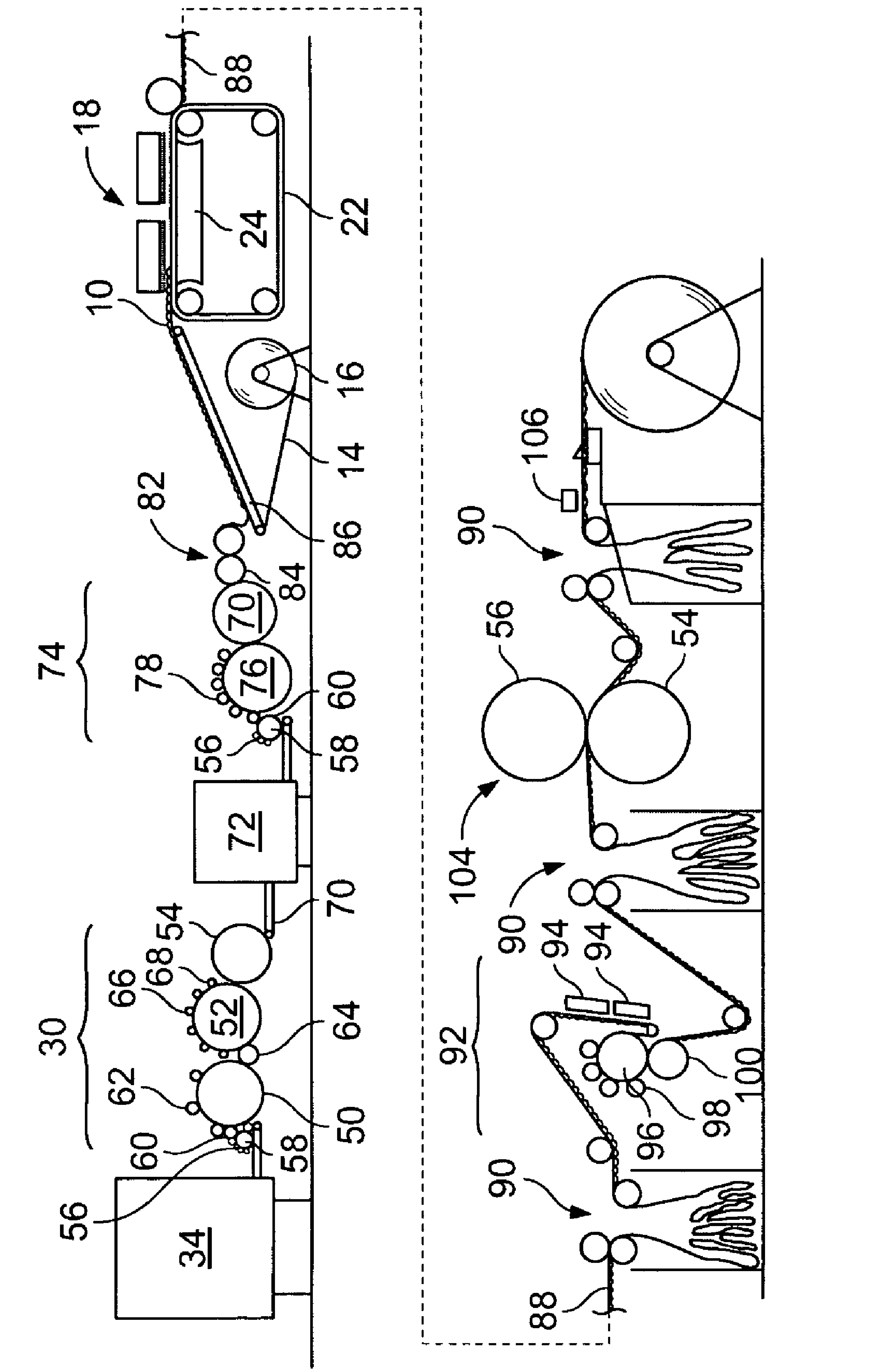

18
88
10
24
22
16
14
82
86
84
74
70
78
76
60
56
58
72
70
30
54
68
66
52
64
62
50
60
58
56
34
90
106
56
54
104
90
94
94
92
96
98
100
90
88

FIG. 1

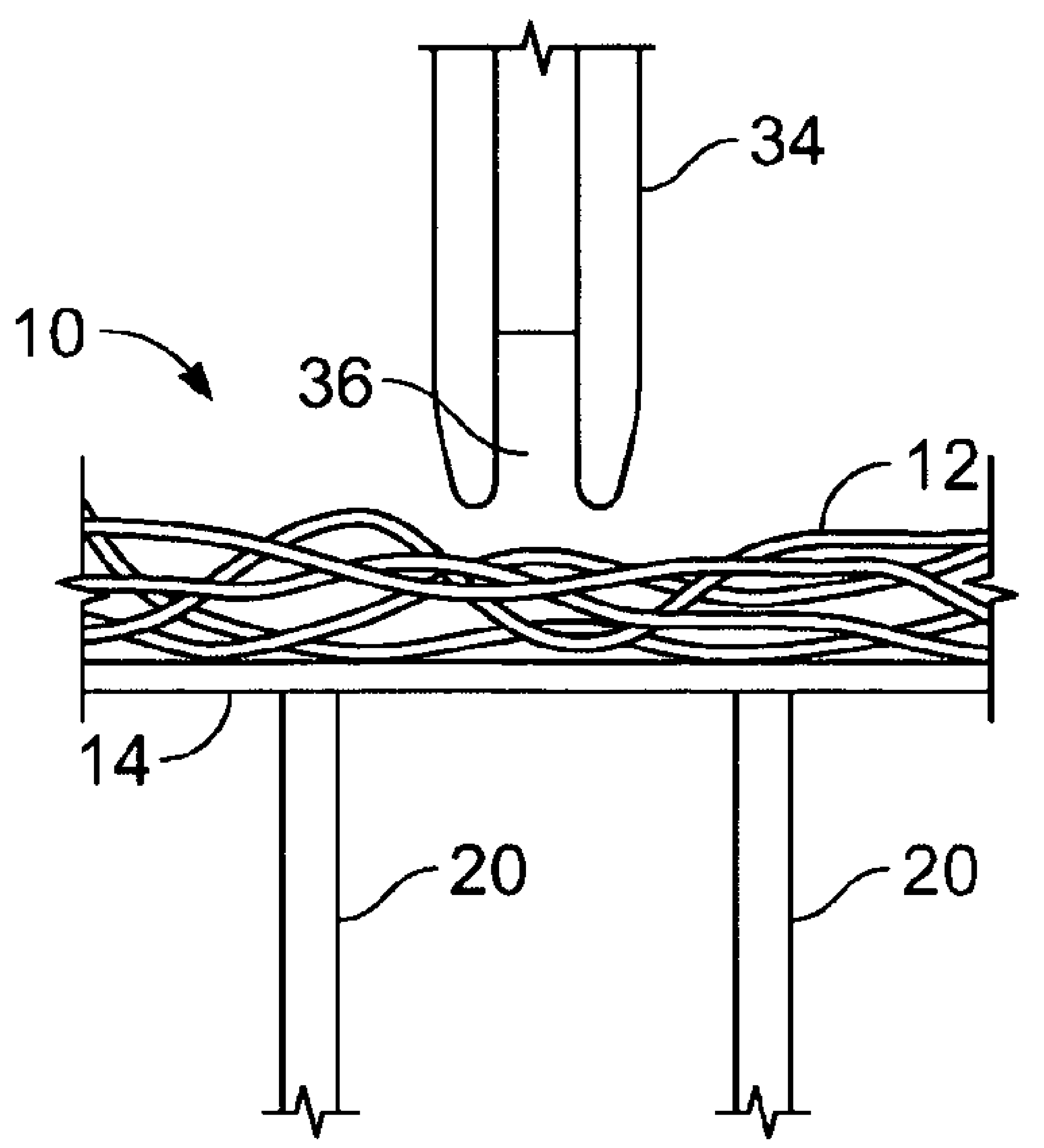


FIG. 2A

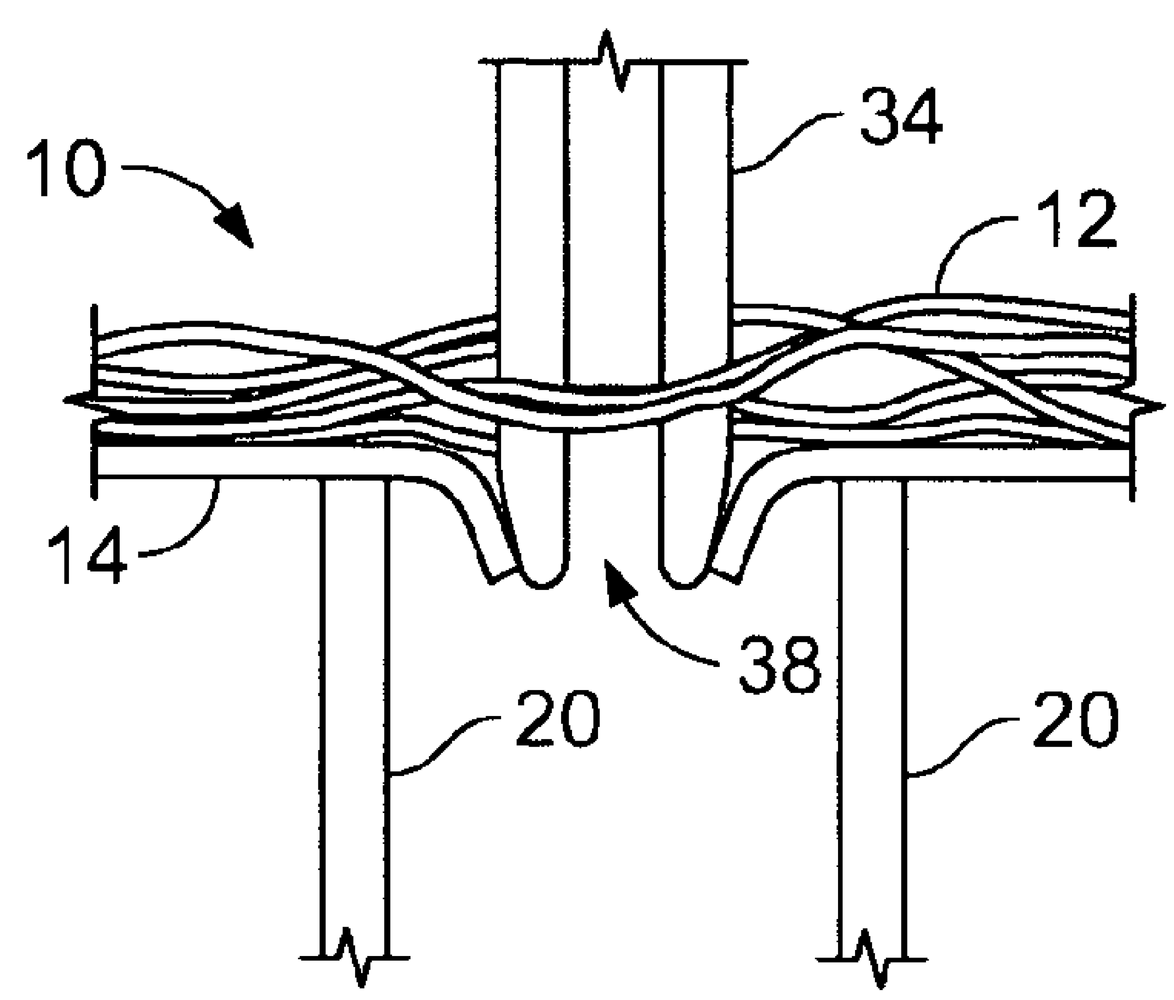


FIG. 2B

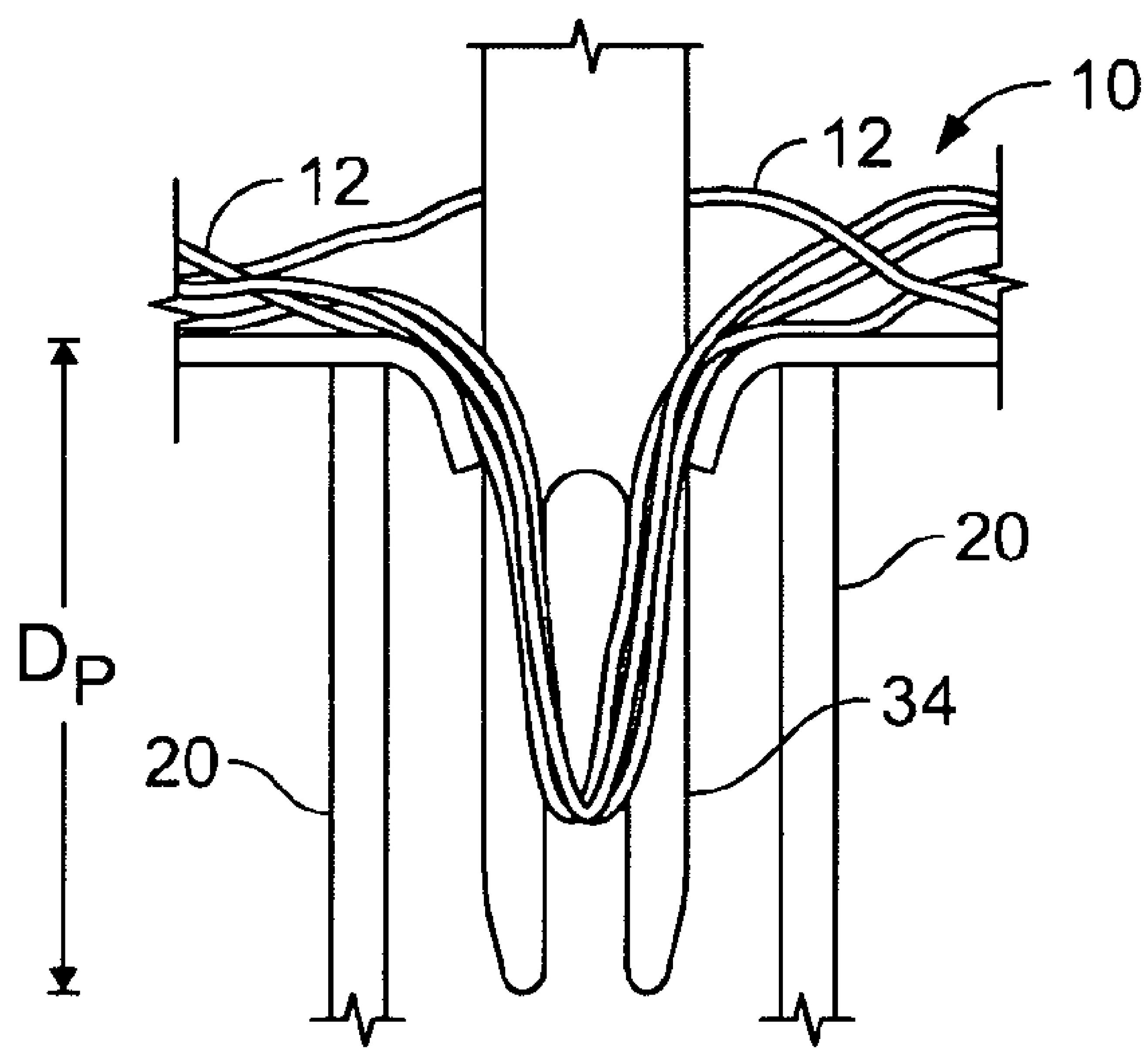


FIG. 2C

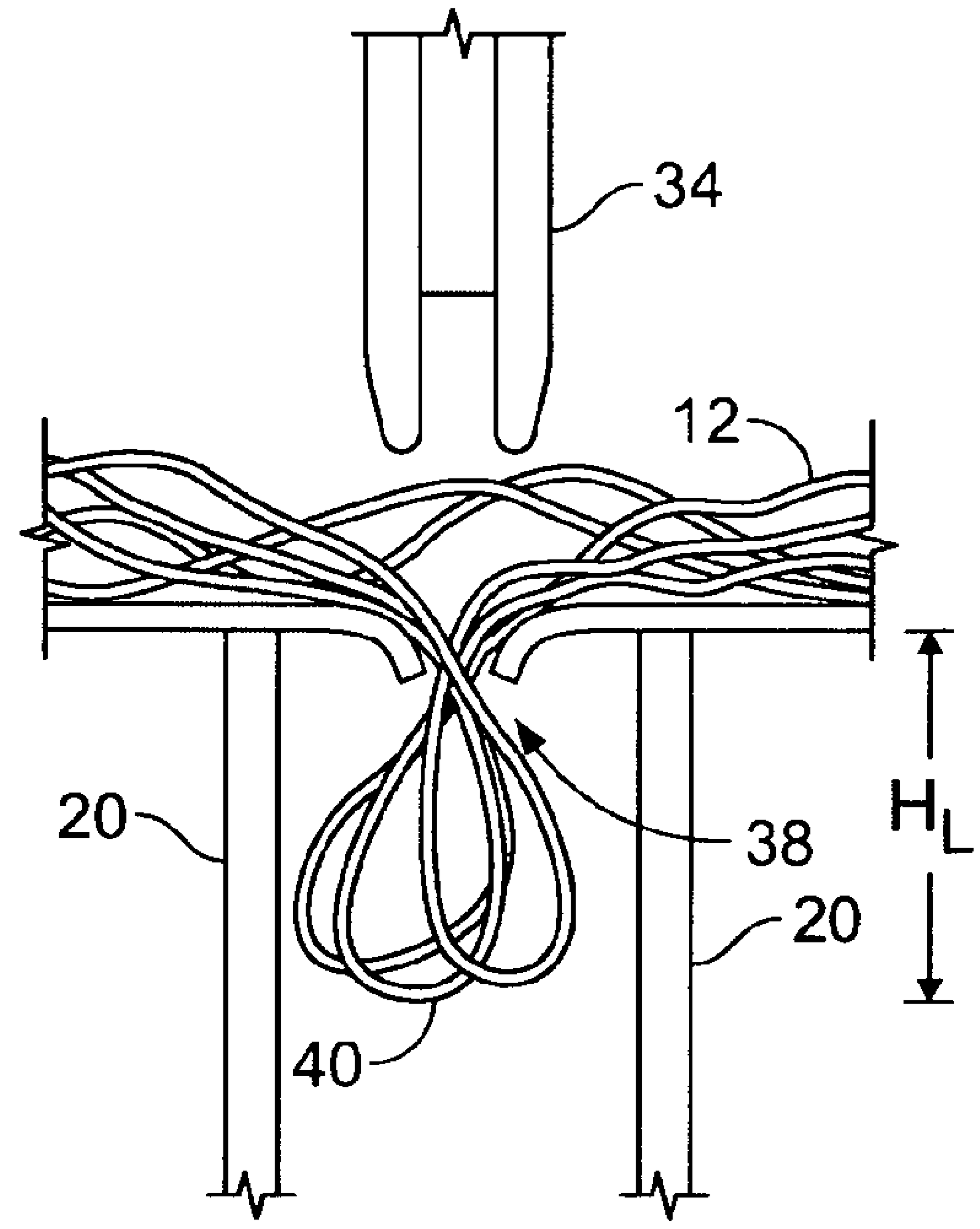


FIG. 2D

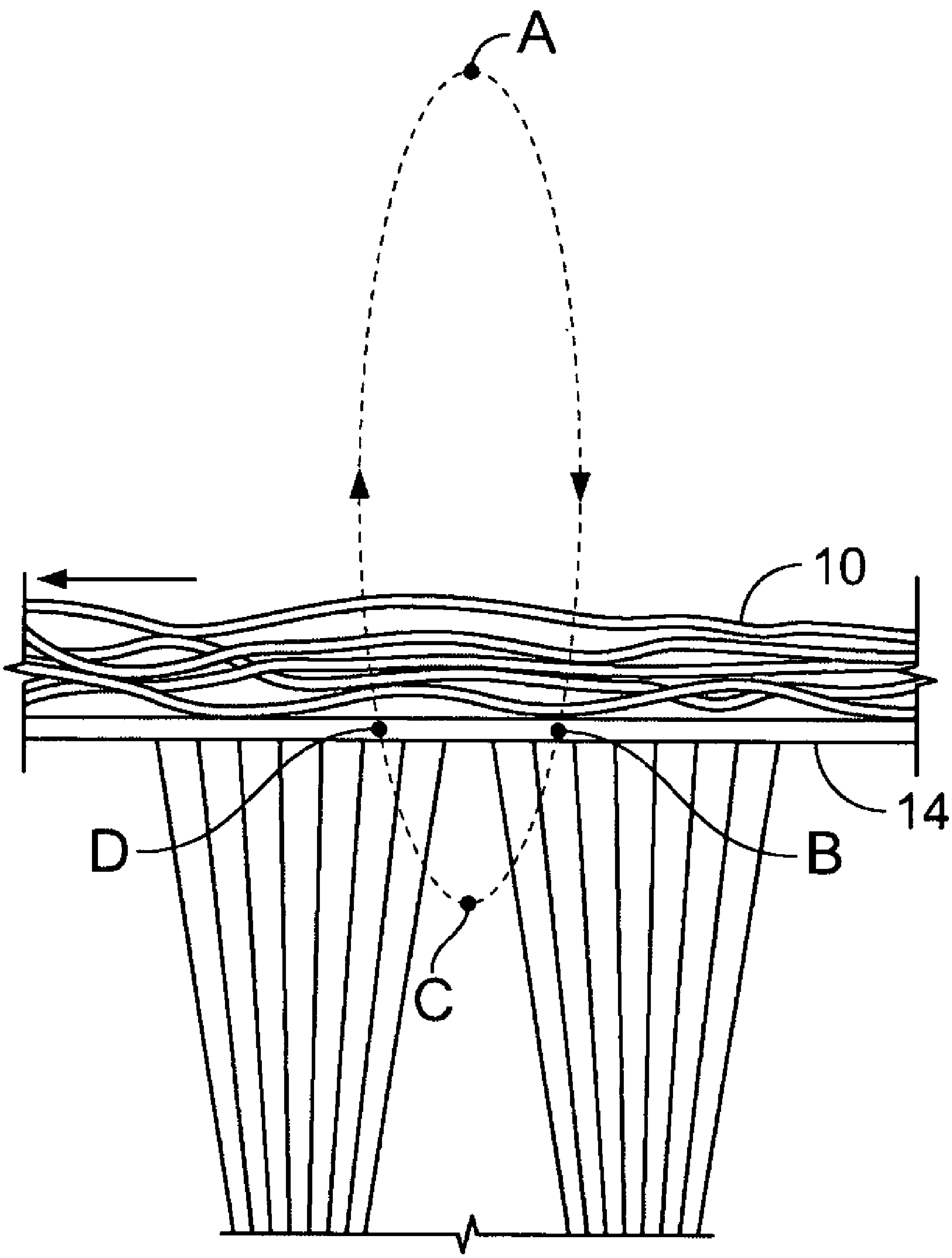


FIG. 2E

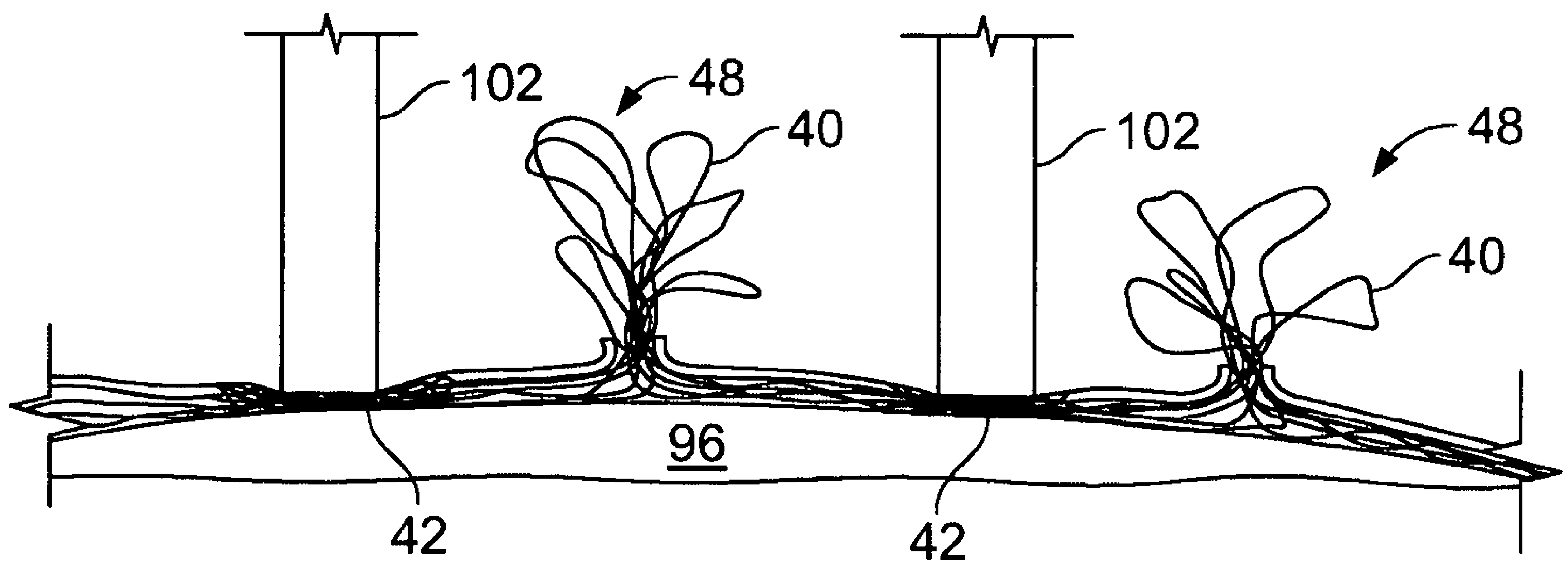


FIG. 3

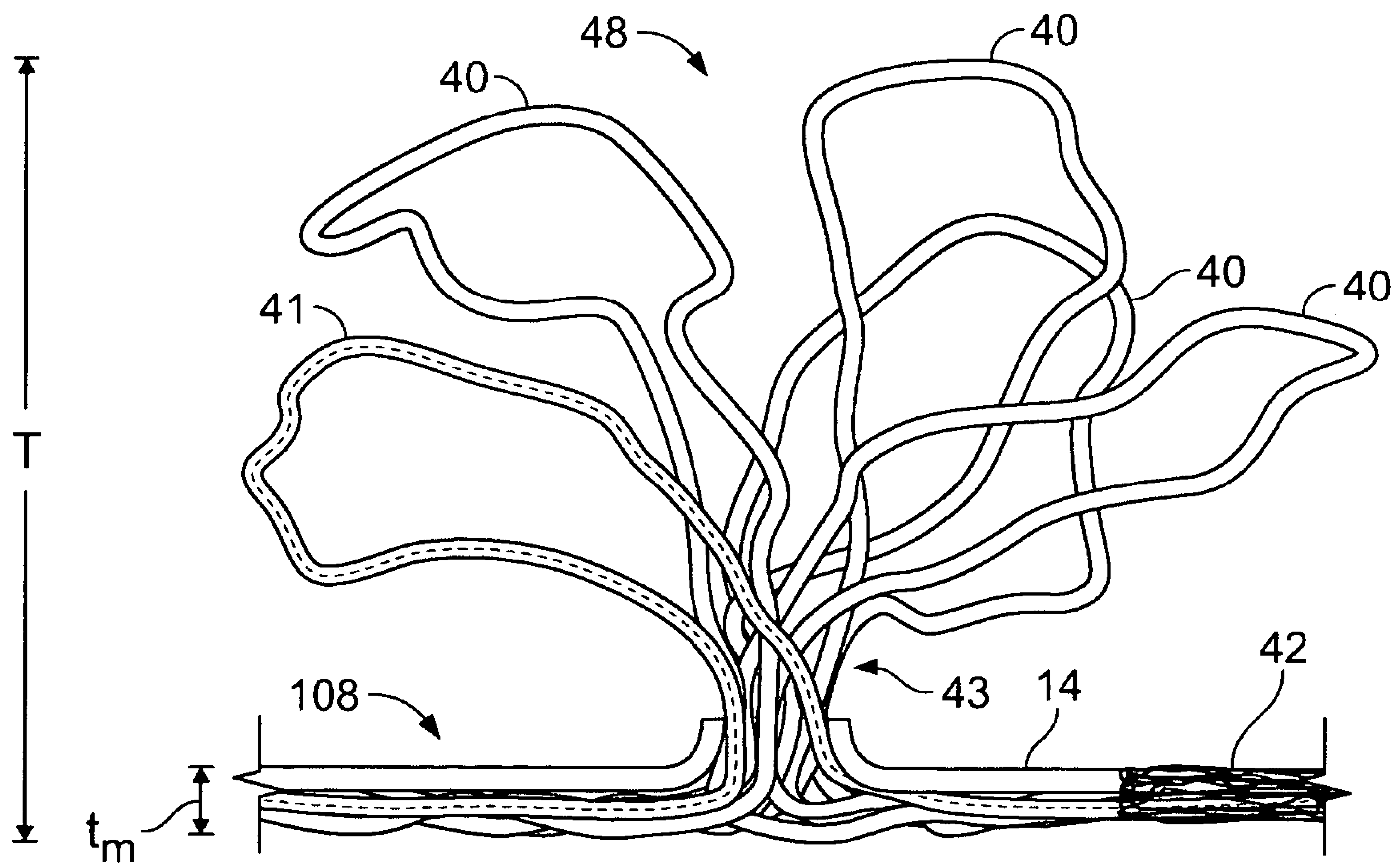


FIG. 4

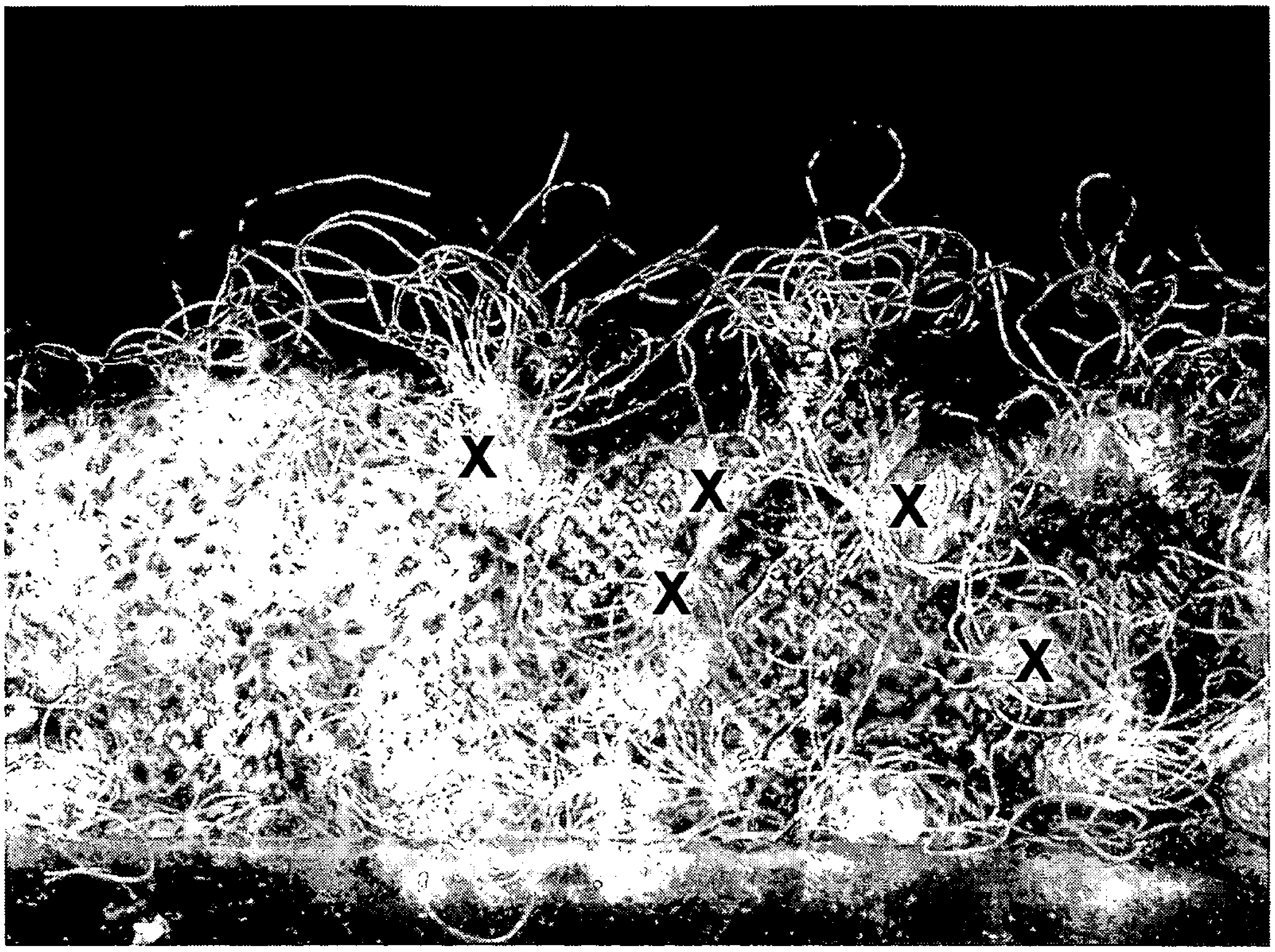


FIG. 4A

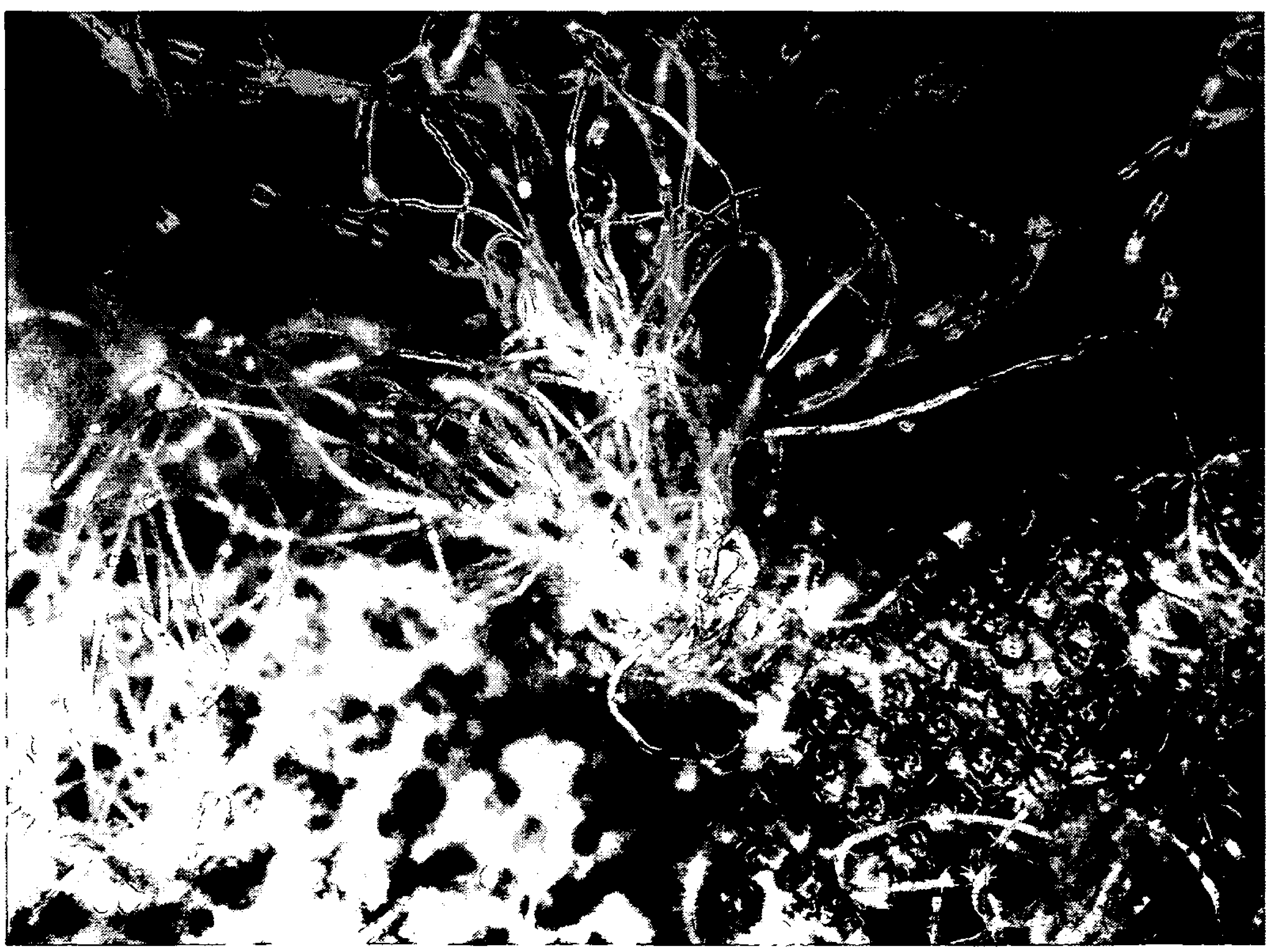


FIG. 4B

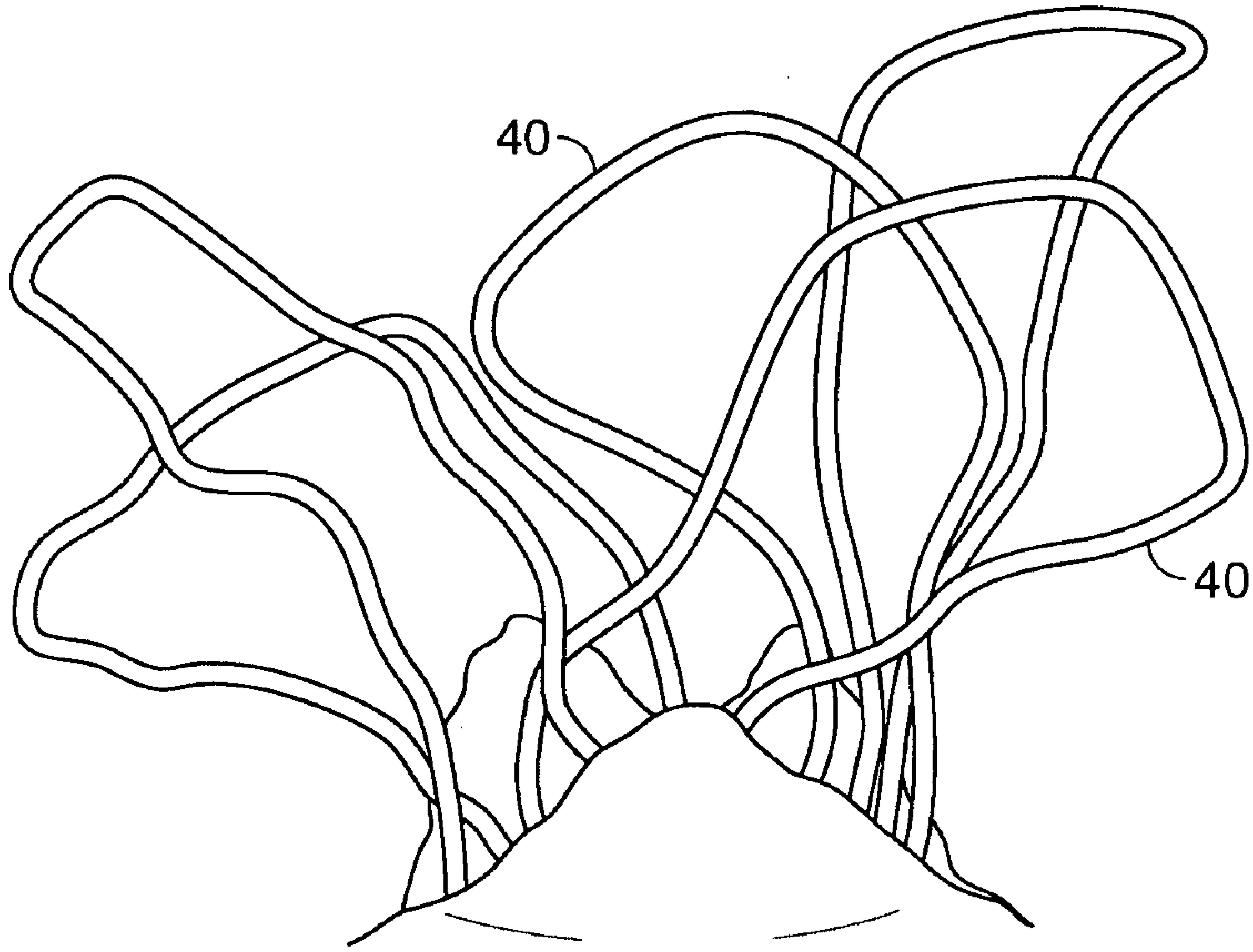


FIG. 4C

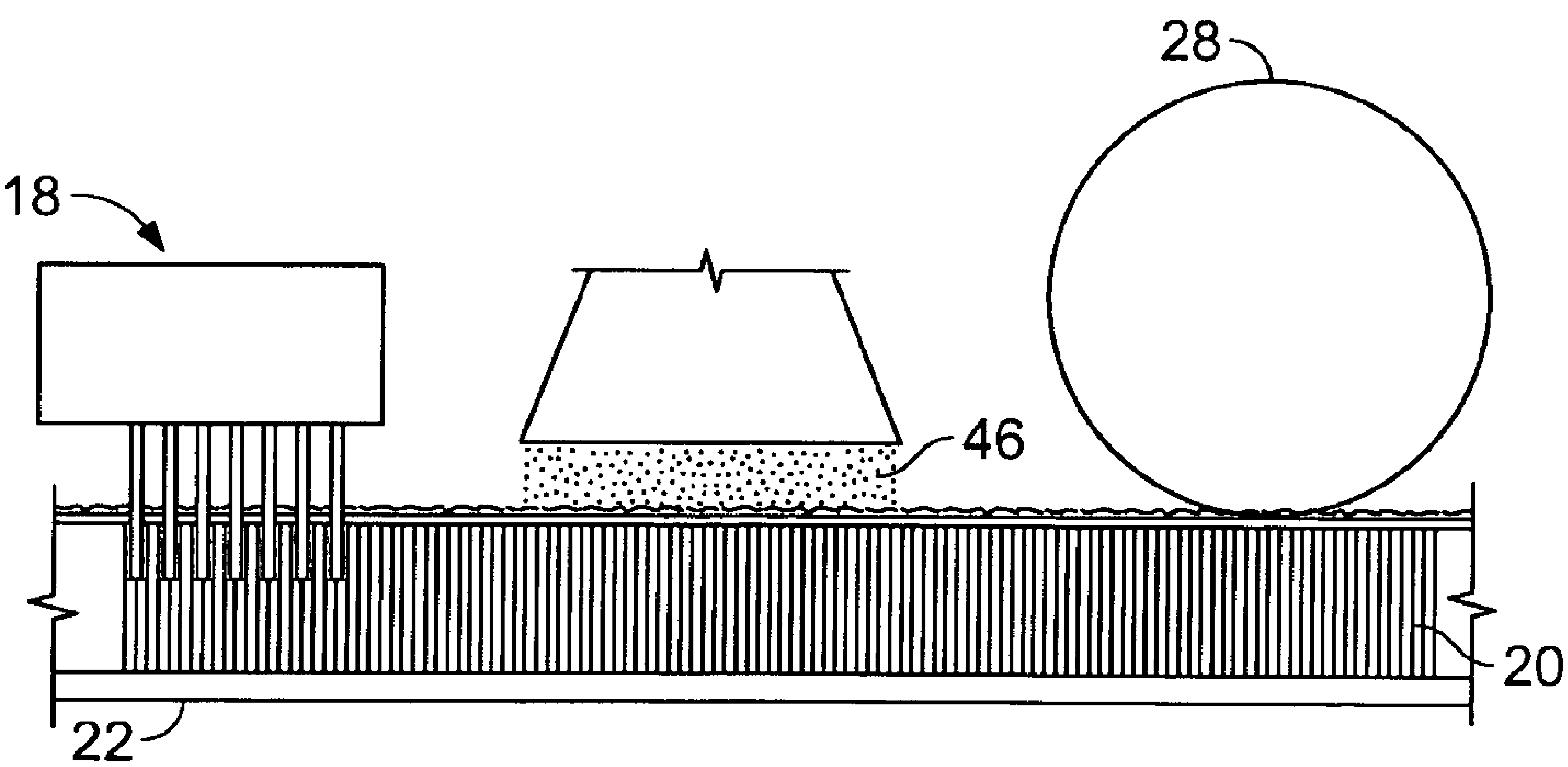


FIG. 5

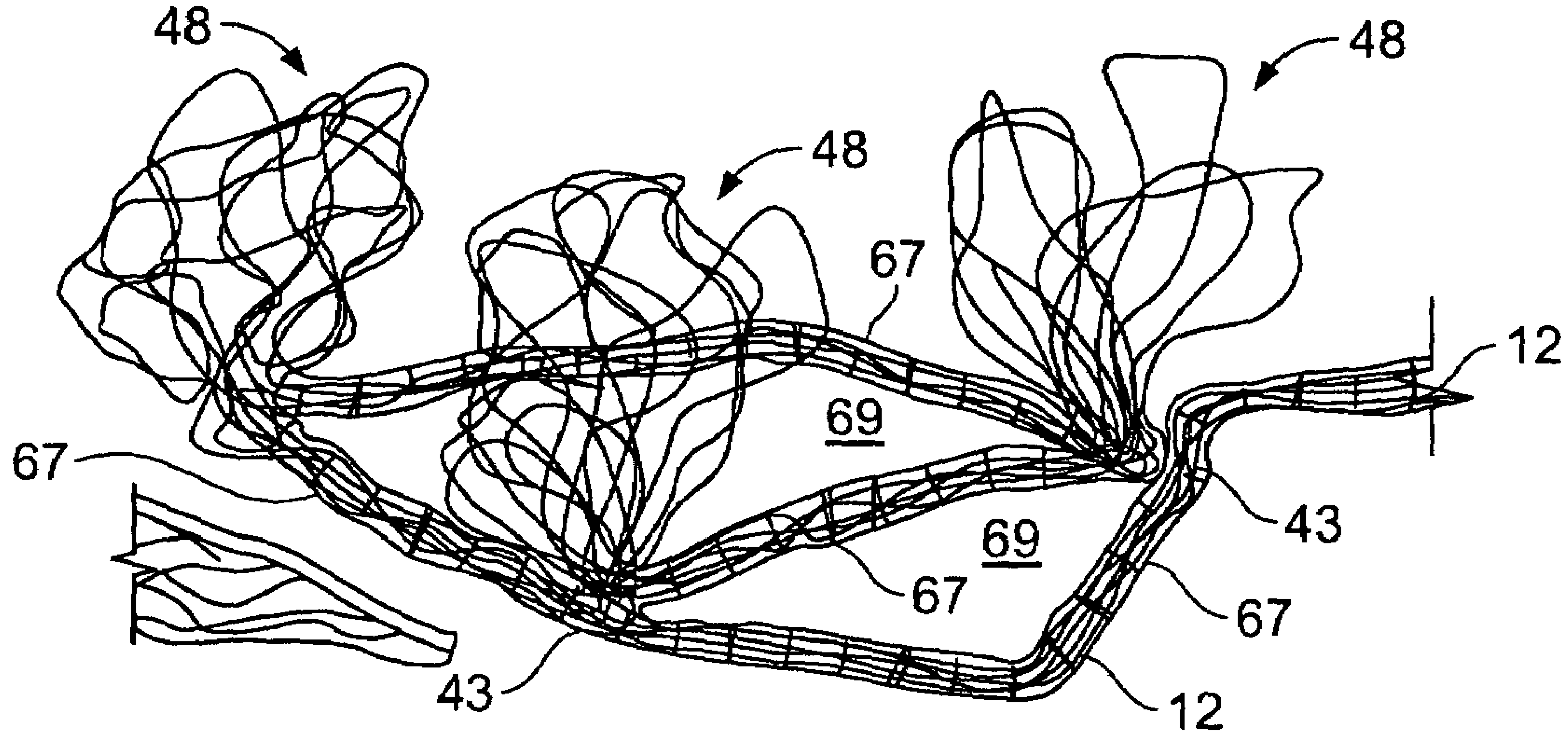


FIG. 6

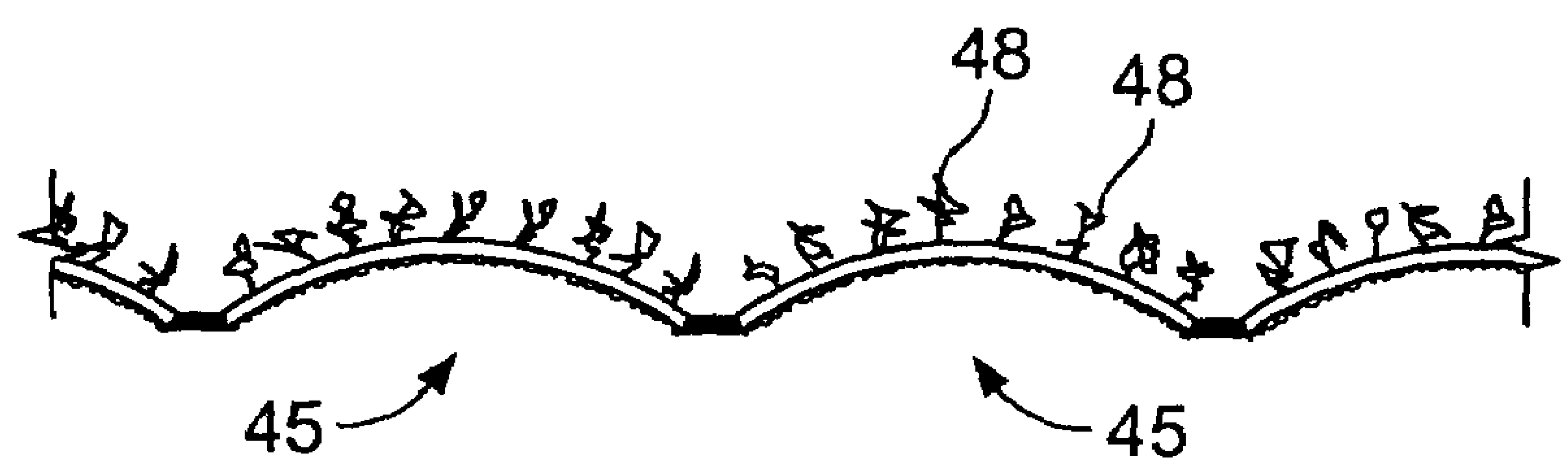


FIG. 7B

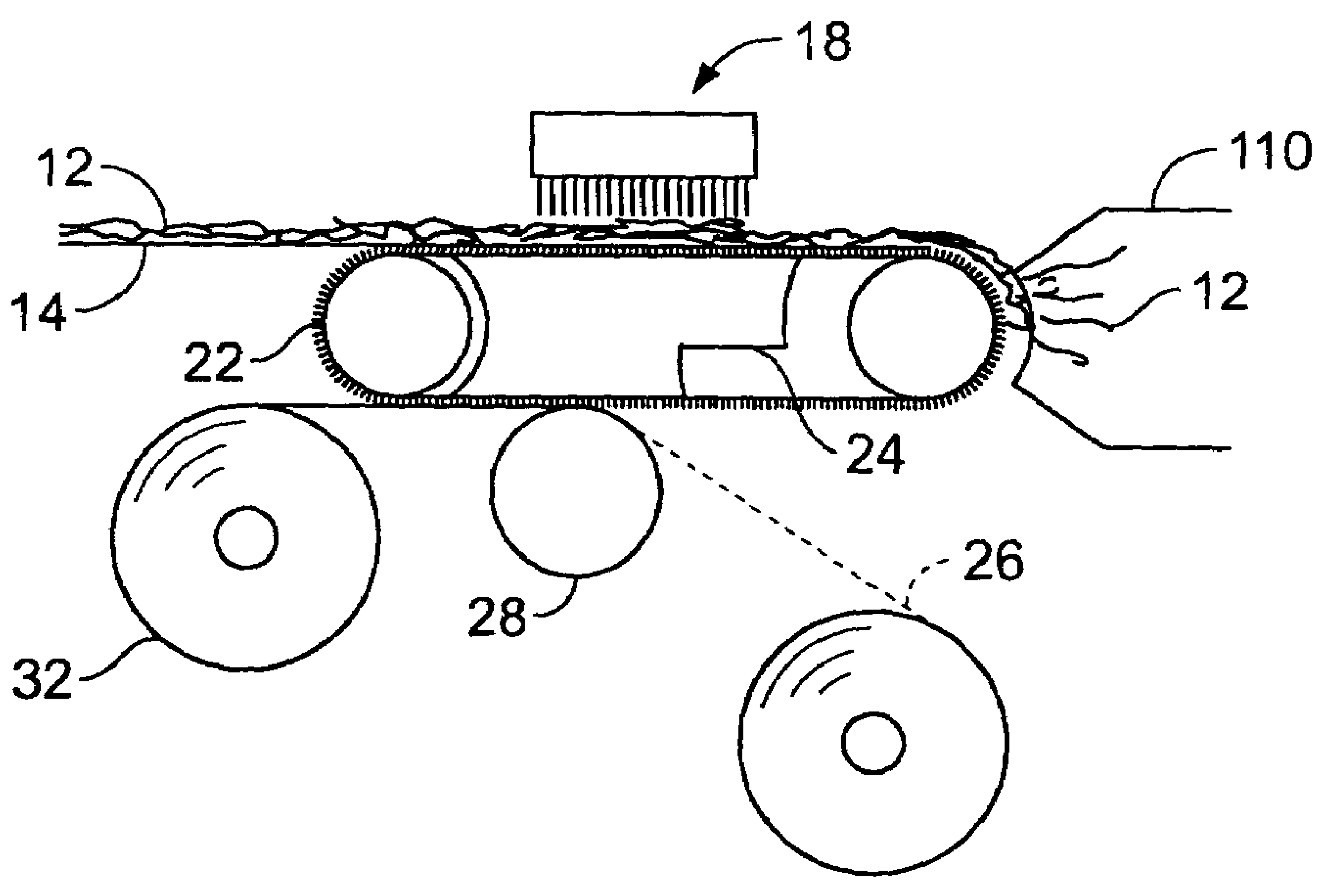


FIG. 8

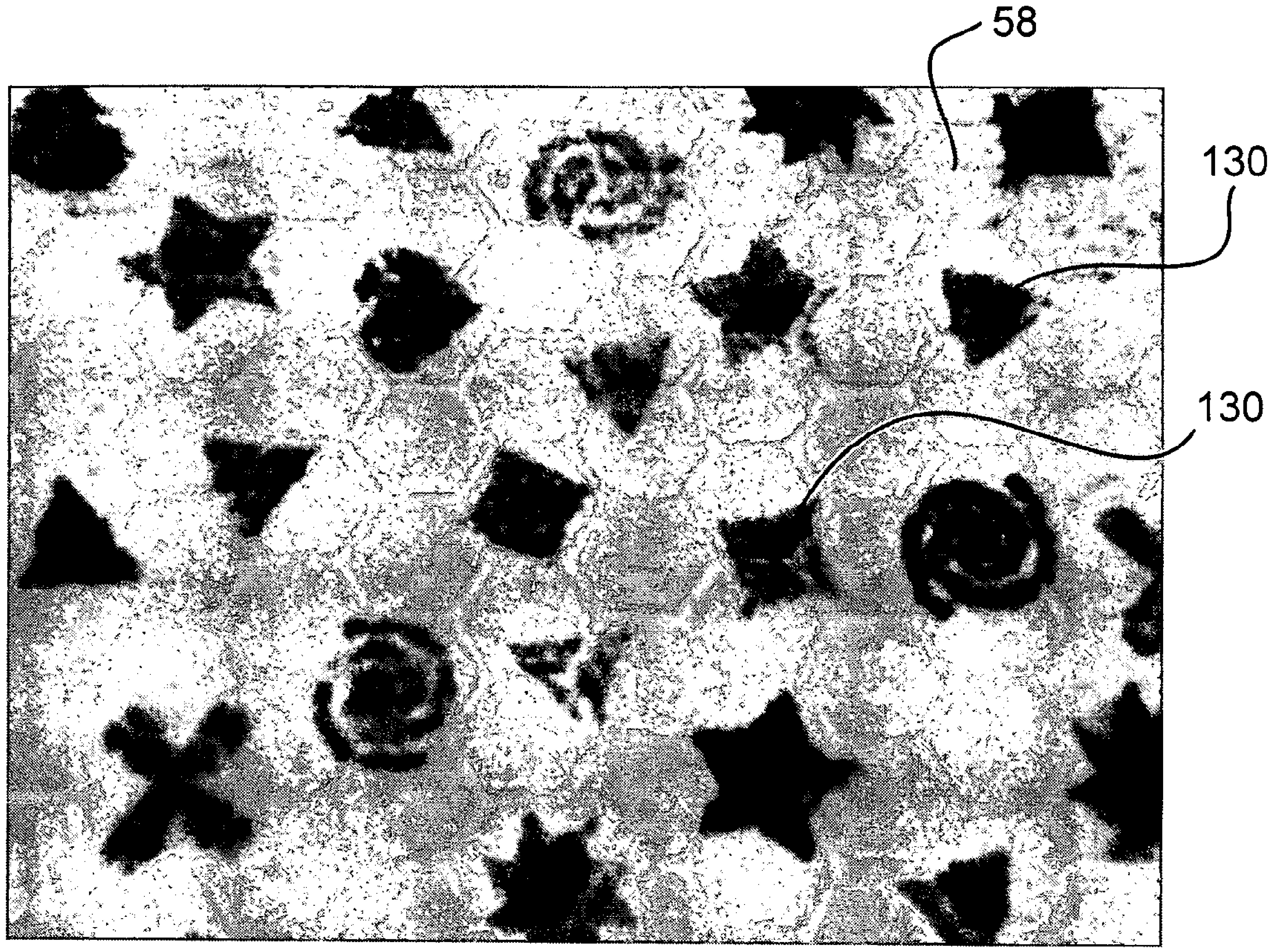


FIG. 7

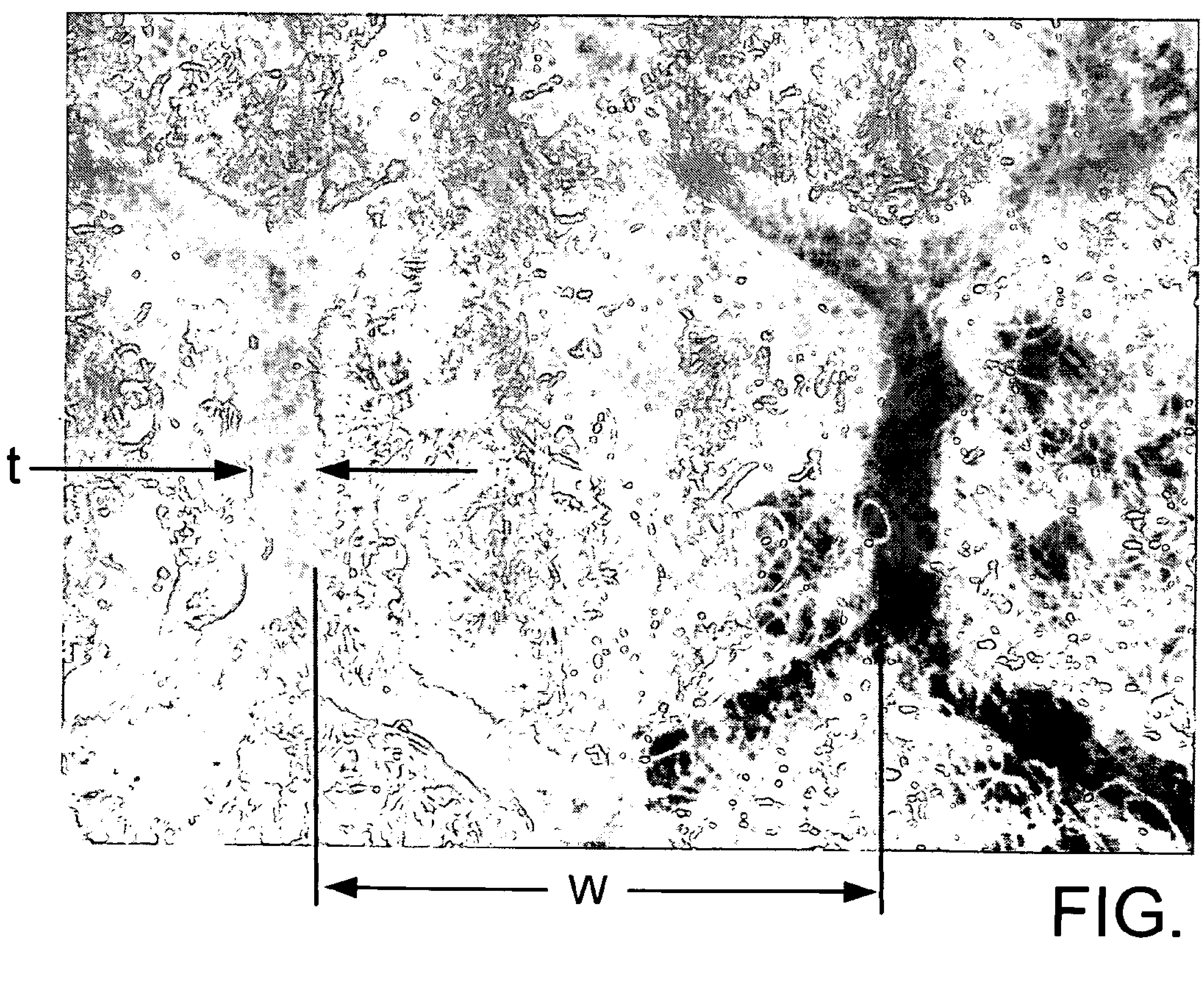


FIG. 7A

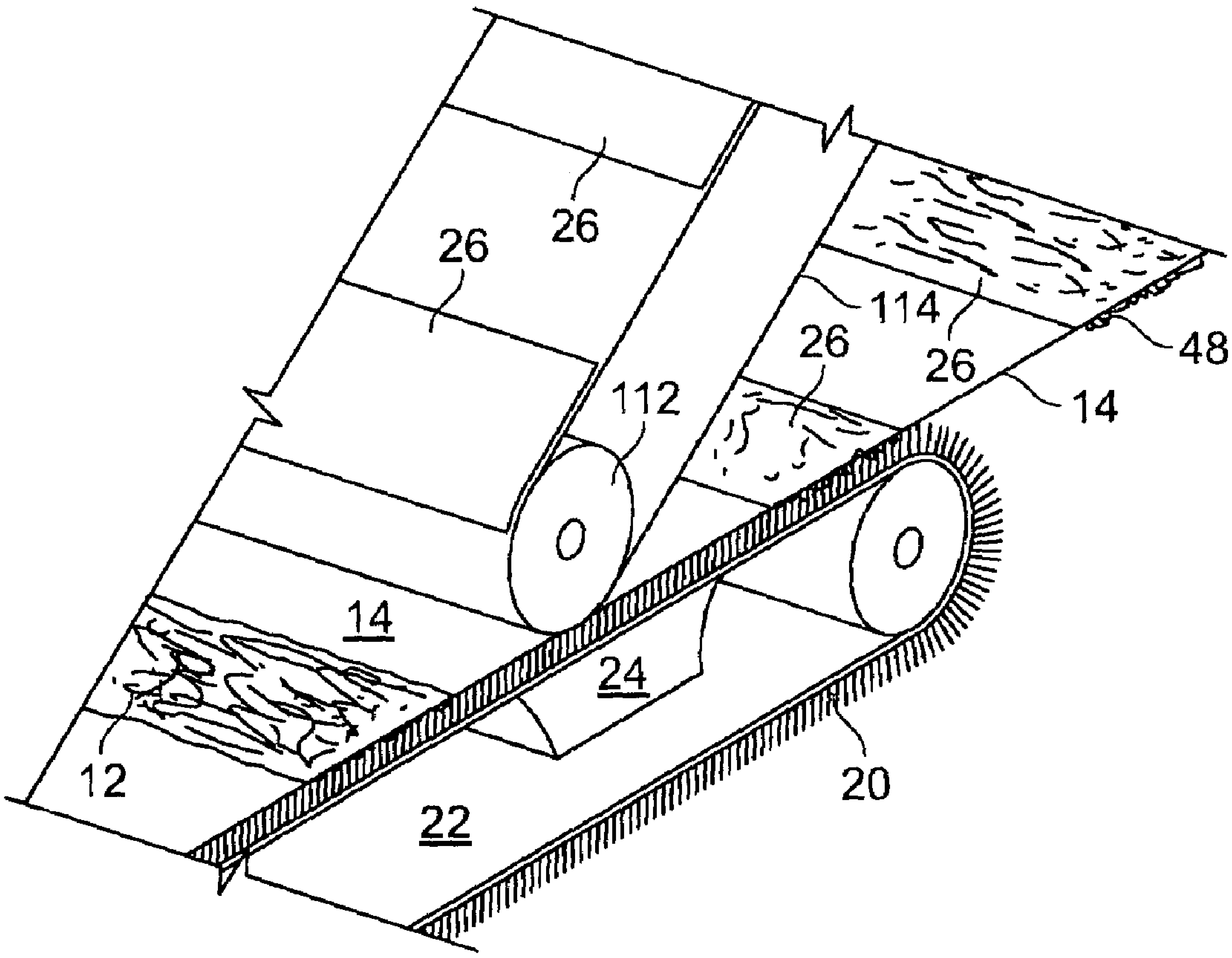


FIG. 9

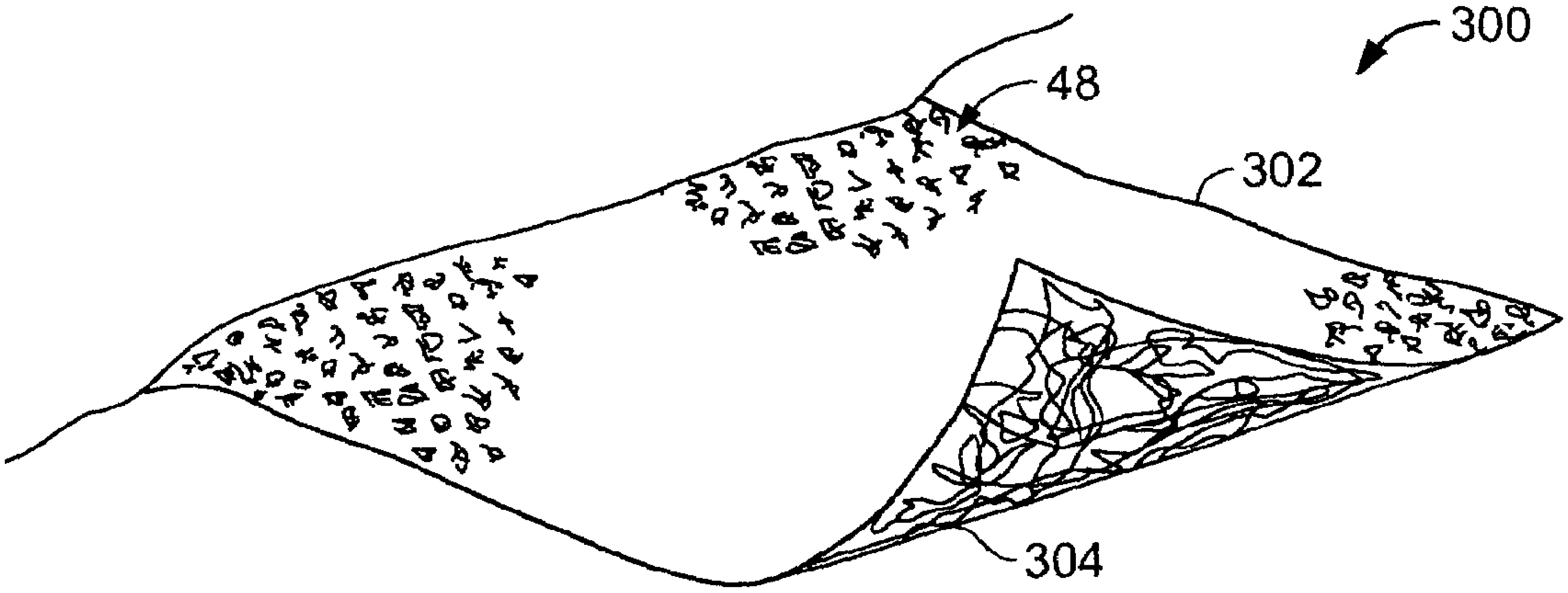


FIG. 10

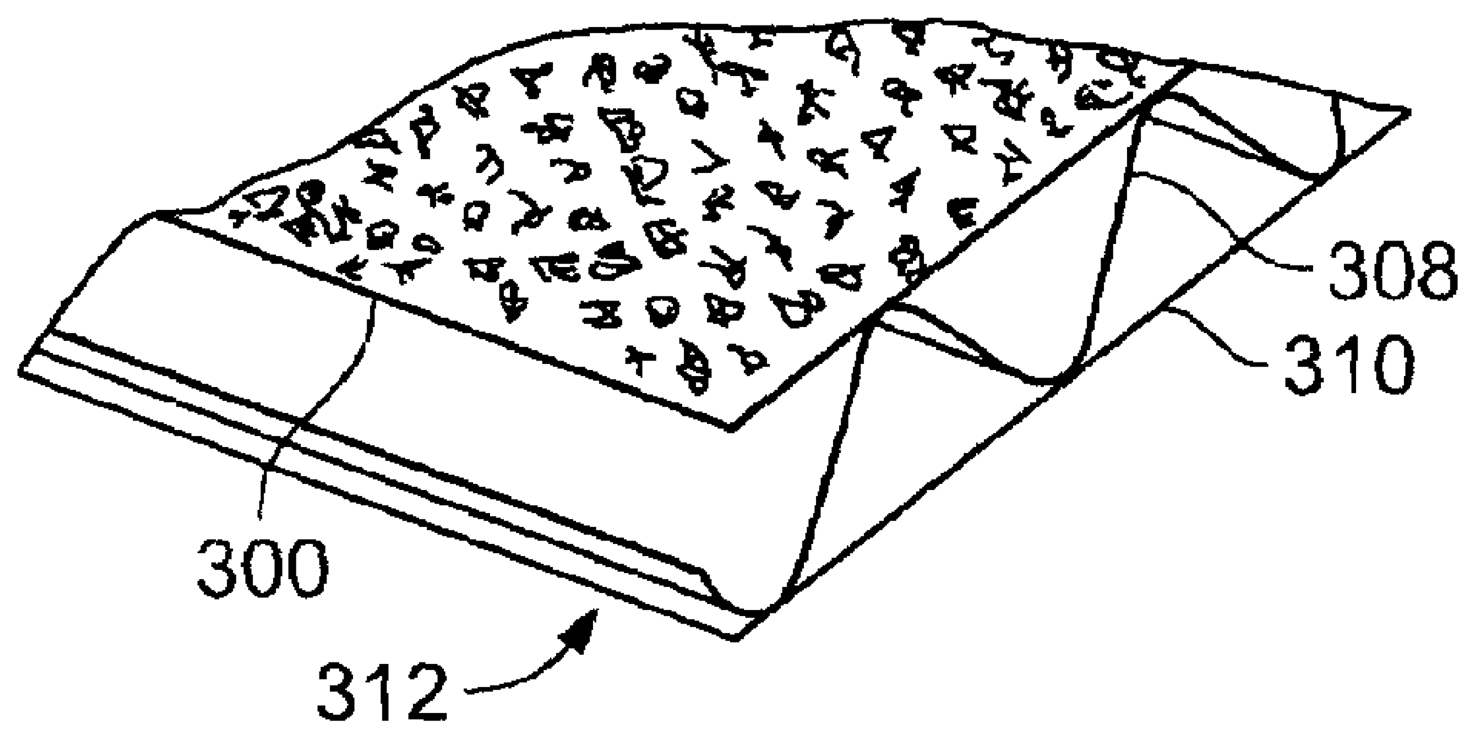


FIG. 11

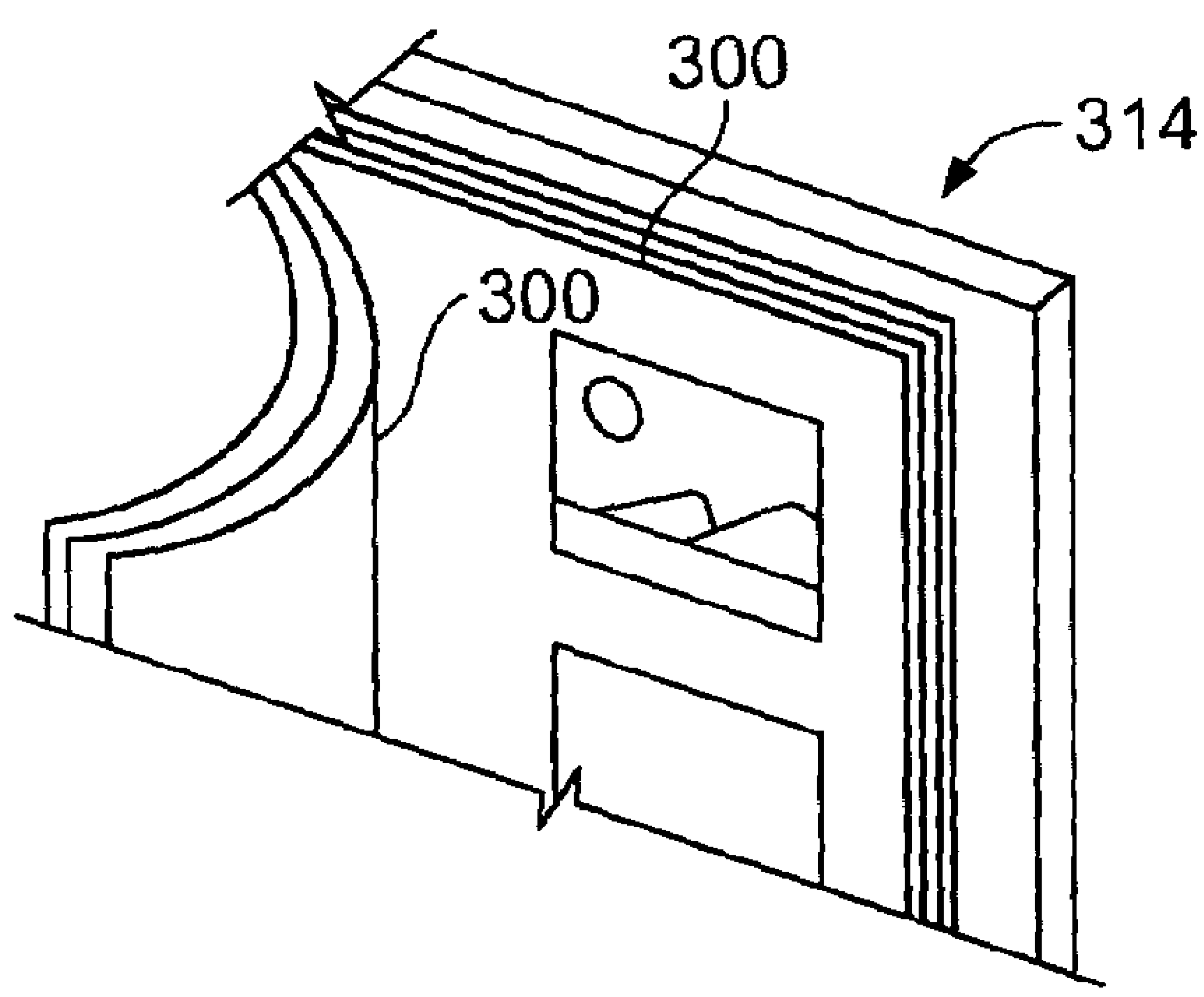


FIG. 12

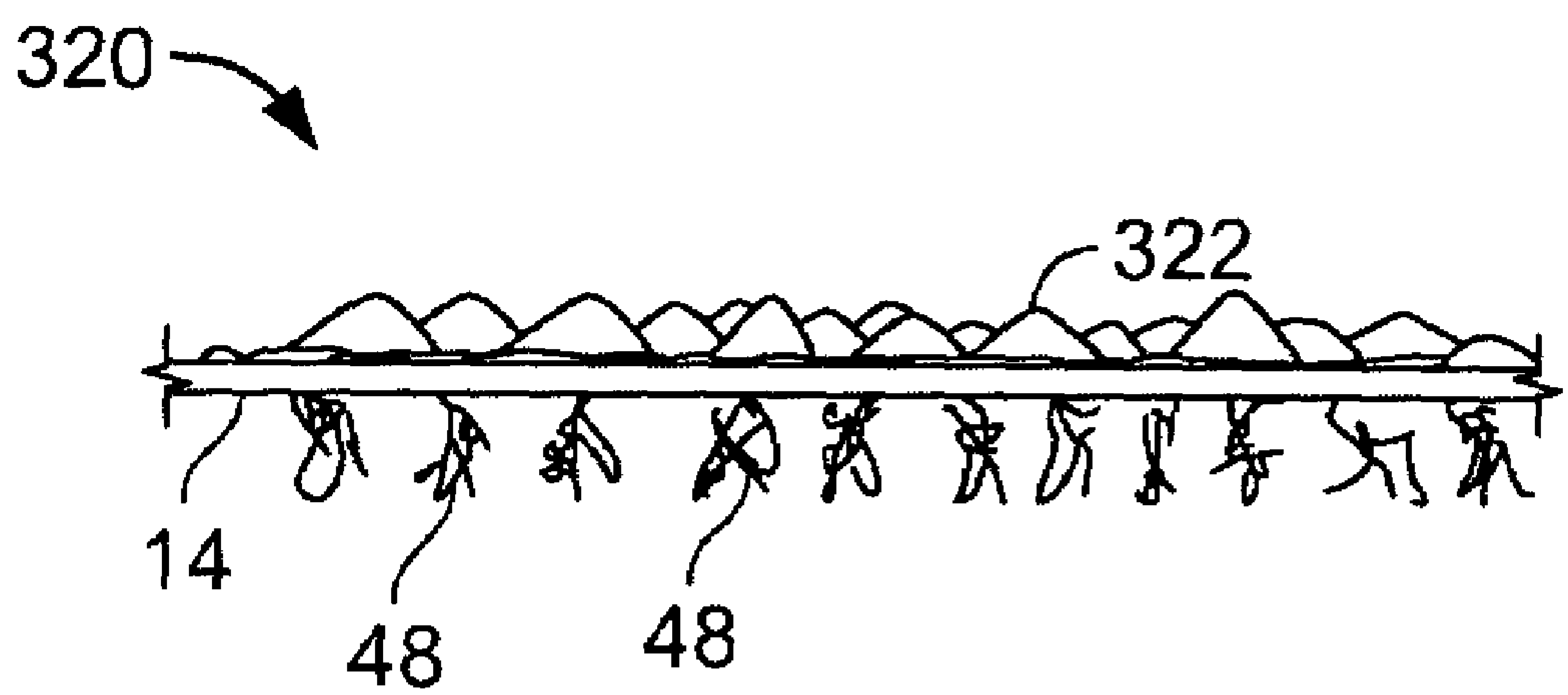


FIG. 13

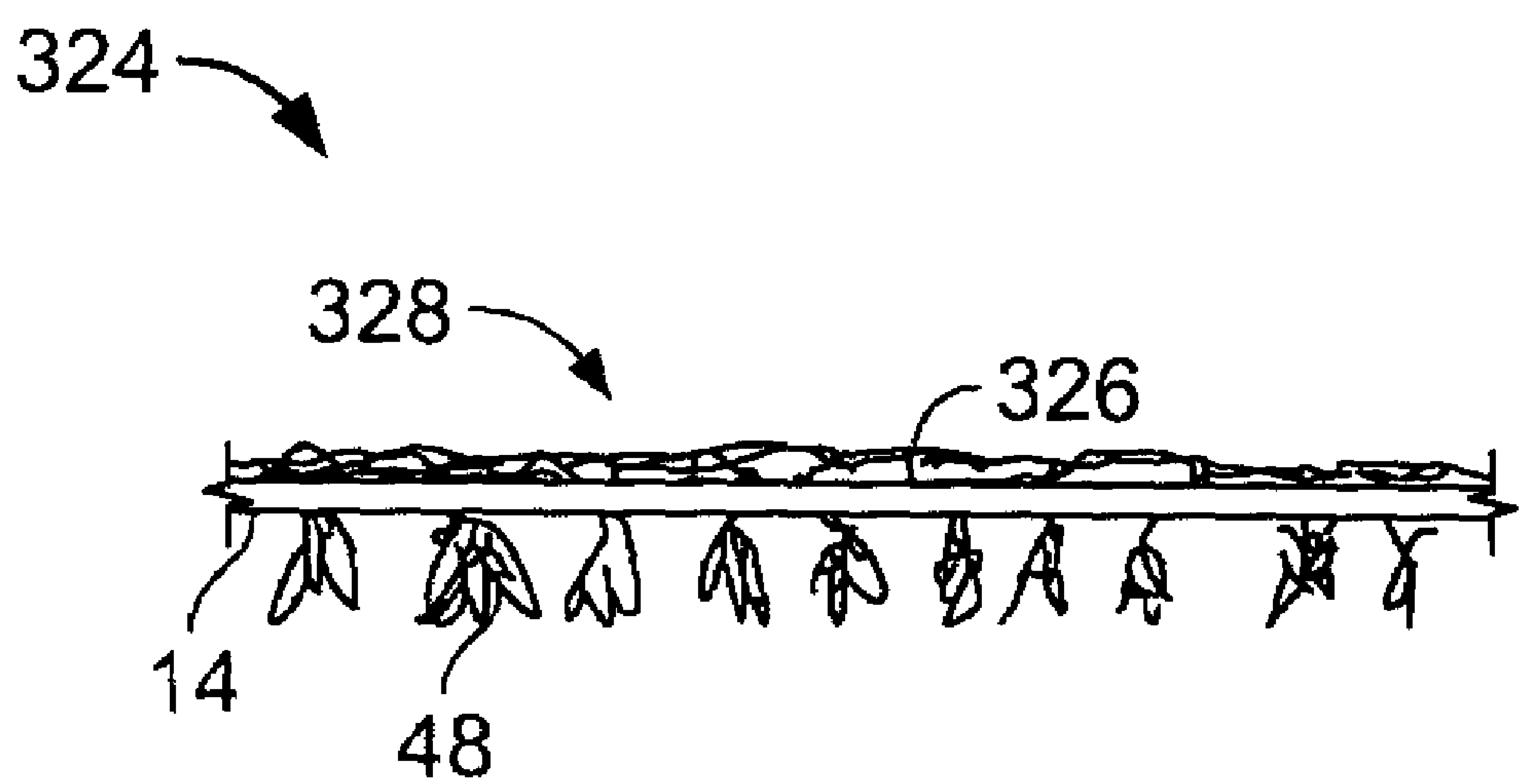


FIG. 14

NEEDLING LOOPS INTO CARRIER SHEETS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part application of, and claims priority under 35 U.S.C. §120 to, U.S. Application Ser. No. 10/728,138, filed on Dec. 3, 2003, now U.S. Pat. No. 7,156,937, and also claims priority under 35 U.S.C. §119(e) to U.S. provisional application 60/430,731, filed on Dec. 3, 2002. The entire contents of both of these priority applications are incorporated herein by reference, as if set forth in their entirety.

TECHNICAL FIELD

This invention relates to methods of making sheet-form loop products, particularly by needling fibers into carrier sheets to form loops, and products produced thereby.

BACKGROUND

Touch fasteners are particularly desirable as fastening systems for lightweight, disposable garments, such as diapers. In an effort to provide a cost-effective loop material, some have recommended various alternatives to weaving or knitting, such as by needling a lightweight layer of fibers to form a light non-woven material that can then be stretched to achieve even lighter basis weight and cost efficiency, with the loop structures anchored by various binding methods, and subsequently adhered to a substrate. U.S. Pat. No. 6,329,016 teaches one such method, for example.

Materials with lower unit costs and better performance are desired. Reducing fiber content can lower cost, but can also affect overall performance or load-carrying capacity of the loop material, as well as the dimensional stability and handling efficiency of the loop product. Also, choice of fiber material is often compromised by a need for the loop material to be weld-compatible with a substrate (e.g., an outer layer of a diaper) to which the loop material is to be permanently bonded.

Various methods of bonding fibers to underlying substrates have also been taught, for forming touch fasteners and other loop-bearing materials.

SUMMARY

In one aspect of the invention, a method of making a sheet-form loop product includes: placing a layer of staple fibers against a first side of a flexible paper substrate; needling fibers of the layer through the paper substrate by piercing the substrate with needles that drag portions of the fibers through holes formed in the paper substrate during needling, leaving exposed loops of the fibers extending from the holes on a second side of the paper substrate; and anchoring fibers forming the loops.

By "paper" we mean flexible sheet-form products made of wood pulp, or synthetic materials formulated to have functional properties essentially the same as those of paper made of wood pulp. It includes a broad range of types of papers, including tissue papers, construction papers, typing paper, newsprint, packaging papers, and others.

In another aspect of the invention, a sheet-form loop product includes: a flexible substrate having a plurality of holes pierced therethrough; and a layer of staple fibers disposed on a first side of the substrate, exposed loops of the fibers extending from the holes on a second side of the substrate, with bases

of the loops being anchored on the first side of the substrate; wherein the substrate comprises paper.

In embodiments of the method, anchoring the fibers can include fusing the fibers on the first side of the substrate to anchor the loops. In some cases, the method also includes heating the fibers from the first side of the substrate prior to fusing. In some cases, the method also includes carding and cross-lapping the fibers prior to disposing the fibers on the substrate.

Anchoring the fibers to the substrate can include laminating the fibers to the substrate by pressing the fibers against the substrate employing a bed of discrete pins that apply pressure to the substrate only at discrete points corresponding to the pins. In some embodiments featuring laminating the fibers to the substrate, the fibers are loose and unconnected to the substrate until laminated. In some cases, the anchoring occurs subsequent to needling.

In some embodiments, the needling includes at least 40 piercings per square centimeter, preferably 60 to 100 piercings per square centimeter.

In some embodiments, the fibers are fused to one another. More particularly, in some cases, the fibers are fused on the first side of the substrate and/or are fused directly to one another.

In some embodiments, the fibers include bicomponent fibers having a core of one material and a sheath of another material, and anchoring the fibers can include melting material of the sheaths of the bicomponent fibers to bind fibers together. In some embodiments with bicomponent fibers, the bicomponent fibers make up only between about 15 and 30 percent of the fibers, by weight.

For touch fastener applications, needling fibers of the layer through the paper substrate and anchoring fibers forming the loops forms loops sized and constructed to be releasably engageable by a field of hooks for hook-and-loop fastening. The fibers preferably have a strength of at least 10 grams and are of a denier of no more than about 6.

In some embodiments of the loop product, the bases of the fibers are anchored at discrete bond points between the holes. In some of these embodiments, the fibers are loose and unconnected except at the bond points.

In some embodiments, the staple fibers are disposed on the substrate in a layer of a total fiber weight of less than about 2 ounces per square yard (67 grams per square meter) (e.g. in a layer of a total fiber weight of no more than about one ounce per square yard (34 grams per square meter)). In some cases, the staple fibers are disposed on the substrate in a carded, unbonded state.

In some embodiments, the loop product has an overall weight of less than about 5 ounces per square yard (167 grams per square meter).

In some embodiments, the holes have a distribution with an overall hole density of more than about 60 holes per square centimeter.

In some embodiments of the loop product, the loops are hook-engageable and the product is a loop fastener product. In some of these embodiments, the loops are formed primarily of fibers having an individual fiber strength of at least 8 grams.

In some cases, the loop product, in a continuous length, is spooled into roll form.

In another aspect of the invention, a disposable towel includes: a sheet of paper having a plurality of holes pierced therethrough; and a layer of staple fibers disposed on a first side of the paper, loops of the fibers extending from the holes on a second side of the paper, with bases of the loops being anchored on the first side of the paper.

In another aspect of the invention, an abrasive scrubbing material includes: a sheet of flexible material having a plurality of holes pierced therethrough; and a layer of staple abrasive fibers disposed on a first side of the flexible material, loops of the fibers extending from the holes on a second side of the flexible material to form a scrubbing surface, with bases of the loops being anchored on the first side of the flexible material. Some embodiments of this aspect of the invention include emery fibers. Some embodiments of this aspect of the invention feature steel fibers.

In another aspect of the invention an abrasive sanding material includes: a sheet of flexible material having a plurality of holes pierced therethrough; and a layer of staple fibers disposed on a first side of the flexible material, loops of the fibers extending from the holes on a second side of the flexible material to form a fastening surface, with bases of the loops being anchored on the first side of the flexible material. Abrasive material is disposed on an opposite side of the flexible material and arranged to be exposed for sanding with the sanding material releasably attached to a support by its fastening surface.

In some cases, the abrasive material is a field of abrasive particles bonded to the flexible material. In some other cases, the fibers are fine metal filaments, such as steel wook, and the abrasive material is portions of such fibers exposed on the opposite side of the flexible material.

With respect to those aspects of the invention featuring paper substrates, we have found paper to be quite suitable for supporting a loose, unconnected layer of carded staple fibers prior to and during needling, and to sufficiently survive fairly dense needling so as to retain many useful properties in the finished product. Even needled, paper substrates can bond readily to polyethylene film, for example, or to many other materials. Paper can enable substantial heating and melting of fibers remaining on the side opposite the loops without degrading the loops. Paper can be pre-printed before needling, with printed images remaining clearly visible even after needling. For paper products exposed to water, such as disposable paper towels, needling staple polymer fibers into the towel can greatly improve the strength of the towel when wet, as the fiber web formed by needling, especially after bonding, maintains some dimensional stability when the underlying paper substrate is thoroughly soaked.

Similarly, the methods disclosed herein can form very lightweight fastener materials and materials of other functional uses, such as abrasive or scrubbing materials, for example. The method enables the use of a very sparse amount of fibers, as compared, for example, to non-woven materials formed exclusively of fibers, as the dimensional stability of the overall product need not be established solely by fiber entanglement, as it is aided by the presence of the substrate. Indeed, a great proportion of the fibers can be inexpensively formed into loops exposed at the functional surface of the sheet-form product, whether for fastening or other purposes. As the material cost of such high-tenacity fibers can be a substantial part of the overall cost of such products, the more efficient use of fiber is a substantial savings.

The details of one or more embodiments of the invention are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the invention will be apparent from the description and drawings, and from the claims.

DESCRIPTION OF DRAWINGS

FIG. **1** is a diagrammatic view of a process for forming loop material.

FIGS. **2A**-**2D** are diagrammatic side views of stages of a needling step of the process of FIG. **1**. FIG. **2E** is a diagrammatic side view showing an elliptical path that may be followed by the needle during needling.

FIG. **3** is an enlarged diagrammatic view of a lamination nip through which the loop material passes during the process of FIG. **1**.

FIG. **4** is a highly enlarged diagrammatic view of a loop structure formed by needling with fork needles through film.

FIG. **4A** is an enlarged photograph of a rolled edge of a loop product formed by needling with fork needles through film, showing several discrete loop structures.

FIG. **4B** is a highly enlarged photograph of one of the loop structures shown in FIG. **4A**.

FIG. **4C** illustrates a loop structure formed by needling with crown needles through polyester film.

FIG. **5** is a diagrammatic view showing an alternative lamination step utilizing a powder-form binder.

FIG. **6** is a highly enlarged diagrammatic view of a loop material according to an embodiment in which the carrier film is substantially disintegrated during needling.

FIG. **7** is a photo of a loop material having an embossed pattern on its loop-carrying surface.

FIG. **7A** is an enlarged view of one of the embossing cells, containing multiple discrete loop structures.

FIG. **7B** is a highly enlarged diagrammatic view of an embossed loop material having convex regions.

FIG. **8** is a diagrammatic view of a process for forming a loop material having discrete regions of loop while removing non-needled fibers from the carrier web.

FIG. **9** is a diagrammatic view of a process for rendering needled portions of a loop product substantially fluid-impermeable.

FIG. **10** shows a loop product consisting essentially of a sheet of paper and fibers that have been needled through the paper.

FIG. **11** is a partial perspective view of a cut corner of a corrugated cardboard, with the product of FIG. **10** serving as one side of the cardboard.

FIG. **12** is a partial perspective view of a scrapbook or photo album with pages formed of the material of FIG. **10**.

FIG. **13** is a partial edge view of a sanding disk or sandpaper, with an array of engageable loops on one side and a field of abrasive particles on the other side.

FIG. **14** is a partial edge view of a sanding disk with fibers forming an array of engageable loops on one side and an abrasive surface on the other side.

Like reference symbols in the various drawings indicate like elements.

DETAILED DESCRIPTION

Descriptions of loop products will follow a description of some methods of making loop products.

FIG. **1** illustrates a machine and process for producing an inexpensive touch fastener loop product. Beginning at the upper left end of FIG. **1**, a carded and cross-lapped layer of fibers **10** is created by two carding stages with intermediate cross-lapping. Weighed portions of staple fibers of different types are fed to the first carding station **30** by a card feeder **34**. Card station **30** includes a 36-inch breast roll **50**, a 60-inch breaker main **52**, and a 50-inch breaker doffer **54**. The first card feedroll drive includes 3-inch feedrolls **56** and a 3-inch cleaning roll on a 13-inch lickerin roll **58**. An 8-inch angle stripper **60** transfers the fiber to breast roll **50**. There are three 8-inch worker roll sets **62** on the breast roll, and a 16-inch breast doffer **64** feeds breaker main **52**, against which seven 8-inch worker sets **66** and a flycatcher **68** run. The carded fibers are combed onto a conveyer **70** that transfers the single fiber layer into a cross-lapper **72**. Before cross-lapping, the carded fibers still appear in bands or streaks of single fiber types, corresponding to the fibrous balls fed to carding station **30** from the different feed bins. Cross-lapping, which normally involves a 90-degree reorientation of line direction, overlaps the fiber layer upon itself and is adjustable to establish the width of fiber layer fed into the second carding station **74**. In this example, the cross-lapper output width is set to approximately equal the width of the carrier into which the fibers will be needled. Cross-lapper **72** may have a lapper apron that traverses a floor apron in a reciprocating motion. The cross-lapper lays carded webs of, for example, about 80 inches (1.5 meters) width and about one-half inch (1.3 centimeters) thickness on the floor apron, to build up several layers of criss-crossed web to form a layer of, for instance, about 80 inches (1.5 meters) in width and about 4 inches (10 centimeters) in thickness, comprising four double layers of carded web. During carding, the fibers are separated and combed into a cloth-like mat consisting primarily of parallel fibers. With nearly all of its fibers extending in the carding direction, the mat has some strength when pulled in the carding direction but almost no strength when pulled in the carding cross direction, as cross direction strength results only from a few entanglements between fibers. During cross-lapping, the carded fiber mat is laid in an overlapping zigzag pattern, creating a mat **10** of multiple layers of alternating diagonal fibers. The diagonal layers, which extend in the carding cross direction, extend more across the apron than they extend along its length.

Cross-lapping the web before the second carding process provides several tangible benefits. For example, it enhances the blending of the fiber composition during the second carding stage. It also allows for relatively easy adjustment of web width and basis weight, simply by changing cross-lapping parameters.

Second carding station **74** takes the cross-lapped mat of fibers and cards them a second time. The feedroll drive consists of two 3-inch feed rolls and a 3-inch cleaning roll on a 13-inch lickerin **58**, feeding a 60-inch main roll **76** through an 8-inch angle stripper **60**. The fibers are worked by six 8-inch worker rolls **78**, the last five of which are paired with 3-inch strippers. A 50-inch finisher doffer **80** transfers the carded web to a condenser **82** having two 8-inch condenser rolls **84**, from which the web is combed onto a carrier sheet **14** fed from spool **16**. The condenser increases the basis weight of the web from about 0.7 osy (ounce per square yard) to about 1.0 osy, and reduces the orientation of the fibers to remove directionality in the strength or other properties of the finished product.

The carrier sheet **14**, such as paper, may be supplied as a single continuous length, or as multiple, parallel strips. For particularly wide webs, it may be necessary or cost effective to introduce two or more parallel sheets, either adjacent or slightly overlapping. The parallel sheets may be unconnected or joined along a mutual edge. The carded, uniformly blended layer of fibers from condenser **82** is carried up conveyor **86** on carrier sheet **14** and into needling station **18**. As the fiber layer enters the needling station, it has no stability other than what may have been imparted by carding and cross-lapping. In other words, the fibers are not pre-needled or felted prior to needling into the carrier sheet. In this state, the fiber layer is not suitable for spooling or accumulating prior to entering the needling station.

In needling station **18**, the carrier sheet **14** and fiber are needle-punched from the fiber side. The needles are guided through a stripping plate above the fibers, and draw fibers through the carrier sheet **14** to form loops on the opposite side. During needling, the carrier sheet is supported on a bed of pins or bristles extending from a driven support belt or brush apron **22** that moves with the carrier sheet through the needling station. Alternatively, carrier sheet **14** can be supported on a screen or by a standard stitching plate (not shown). Reaction pressure during needling is provided by a stationary reaction plate **24** underlying apron **22**. In this example, needling station **18** needles the fiber-covered carrier sheet **14** with an overall penetration density of about 80 to 160 punches per square centimeter. At this needling density, we have found that 38 gauge forked tufting needles were small enough to not obliterate the paper, leaving sufficient paper interconnectivity that the paper continued to exhibit some dimensional stability within its plane. During needling, the thickness of the carded fiber layer only decreases by about half, as compared with felting processes in which the fiber layer thickness decreases by one or more orders of magnitude. As fiber basis weight decreases, needling density may need to be increased. The needling station **18** may be a "structuring loom" configured to subject the fibers and carrier web to a random velouring process. Thus, the needles penetrate a moving bed of bristles arranged in an array (brush apron **22**). The brush apron may have a bristle density of about 2000 to 3000 bristles per square inch (310 to 465 bristles per square centimeter), e.g., about 2570 bristles per square inch (400 per square centimeter). The bristles are each about 0.018 inch (0.46 millimeter) in diameter and about 20 millimeters long, and are preferably straight. The bristles may be formed of any suitable material, for example 6/12 nylon. Suitable brushes may be purchased from Stratosphere, Inc., a division of Howard Brush Co., and retrofitted onto DILO and other random velouring looms. Generally, the brush apron moves at the desired line speed.

FIGS. **2**A through **2**D sequentially illustrate the formation of a loop structure by needling. As a forked needle enters the fiber mat **10** (FIG. **2**A), some individual fibers **12** will be captured in the cavity **36** in the forked end of the needle. As needle **34** pierces paper **14** (FIG. **2**B), these captured fibers **12** are drawn with the needle through the hole **38** formed in the paper to the other side of the paper. As shown, paper **14** remains generally supported by pins **20** through this process, the penetrating needle **34** entering a space between adjacent pins. Alternatively, paper **14** can be supported by a screen or stitching plate (not shown) that defines holes aligned with the needles. As needle **34** continues to penetrate (FIG. **2**C), tension is applied to the captured fibers, drawing mat **10** down against paper **14**. In this example, a total penetration depth "D_p" of about 5.0 millimeters, as measured from the entry surface of paper **14**, was found to provide a well-formed loop structure without overly stretching fibers in the remaining mat. Excessive penetration depth can draw loop-forming fibers from earlier-formed tufts, resulting in a less robust loop field. Penetration depths of 2 and 7 millimeters are also suitable, although the 5.0 millimeter penetration is presently preferred. When needle **34** is retracted (FIG. **2**D), the portions of the captured fibers **12** carried to the opposite side of the carrier web remain in the form of a plurality of individual loops **40** extending from a common trunk **42** trapped in paper hole **38**. When film is employed as the carrier sheet, residual stresses in the film around the hole, acting to try to restore the film to its planar state, can apply a slight pressure to the fibers in the hole, helping to secure the base of the loop structure. The film can also help to resist tension applied to the fiber remaining on the mat side of the film that would tend to pull the loops back through the hole. The final loop formation preferably has an overall height "H_L" of about 0.040 to 0.090 inch (1.0 to 2.3 millimeters), for engagement with the size of male fastener elements commonly employed on disposable garments and such.

Advance per stroke is limited due to a number of constraints, including needle deflection and potential needle breakage. Thus, it may be difficult to accommodate increases in line speed and obtain an economical throughput by adjusting the advance per stroke. As a result, the holes pierced by the needles may become elongated, due to the travel of the carrier sheet while the needle is interacting with the carrier sheet (the "dwell time"). This elongation is generally undesirable, as it reduces the amount of support provided to the base of each of the loop structures by the surrounding substrate, and may adversely affect resistance to loop pull-out. Moreover, this elongation will tend to reduce the mechanical integrity of the carrier film due to excessive drafting, i.e., stretching of the film in the machine direction and corresponding shrinkage in the cross-machine direction.

Elongation of the holes may be reduced or eliminated by causing the needles to travel in a generally elliptical path, viewed from the side. This elliptical path is shown schematically in FIG. **2**E. Referring to FIG. **2**E, each needle begins at a top "dead" position A, travels downward to pierce the film (position B) and, while it remains in the film (from position B through bottom "dead" position C to position D), moves forward in the machine direction. When the needle has traveled upward sufficiently for its tip to have exited the pierced opening (position D), it continues to travel upward, free of the film, while also returning horizontally (opposite to the machine direction) to its normal, rest position (position A), completing the elliptical path. This elliptical path of the needles is accomplished by moving the entire needle board simultaneously in both the horizontal and vertical directions. Needling in this manner is referred to herein as "elliptical needling." Needling looms that perform this function are available from DILO System Group, Eberbach, Germany, under the tradename "HYPERPUNCH Systems."

During elliptical needling, the horizontal travel of the needle board is preferably roughly equivalent to the distance that the film advances during the dwell time. The horizontal travel is a function of needle penetration depth, vertical stroke length, carrier film thickness, and advance per stroke. Generally, at a given value of needle penetration and film thickness, horizontal stroke increases with increasing advance per stroke. At a fixed advance per stroke, the horizontal stroke generally increases as depth of penetration and web thickness increases.

For example, for a very thin paper having a thickness of 0.013 millimeter (so thin that it is not taken into account), a loom outfeed of 18.9 meters per minute, an effective needle density of 15,006 needles/meter, a vertical stroke of 35 mm, a needle penetration of 5.0 mm, and a headspeed of 2,010 strokes/min, the preferred horizontal throw (i.e., the distance between points B and D in FIG. **2**E) would be 3.3 mm, resulting in an advance per stroke of 9.4 mm.

Using elliptical needling, it may be possible to obtain line speeds 30 ypm (yards/minute) or mpm (meters/minute) or greater, e.g., 50 ypm or mpm, for example 60 ypm. Such speeds may be obtained with minimal elongation of the holes, for example the length of the holes in the machine direction may be less than 20 percent greater than the width of the holes in the cross-machine direction, preferably less than 10 percent greater and in some instances less than 5 percent greater.

For needling longitudinally discontinuous regions of the material, such as to create discrete loop regions as discussed further below, the needle boards can be populated with needles only in discrete regions, and the needling action paused while the material is indexed through the loom between adjacent loop regions. Effective pausing of the needling action can be accomplished by altering the penetration depth of the needles during needling, including to needling depths at which the needles do not penetrate the carrier sheet. Such needle looms are available from FEHRER AG in Austria, for example. Alternatively, means can be implemented to selectively activate smaller banks of needles within the loom according to a control sequence that causes the banks to be activated only when and where loop structures are desired. Lanes of loops can be formed by a needle loom with lanes of needles separated by wide, needle-free lanes.

In the example illustrated, the needled product **88** leaves needling station **18** and brush apron **22** in an unbonded state, and proceeds to a lamination station **92**. If the needling step was performed with the carrier sheet supported on a bed of rigid pins, lamination can be performed with the carrier sheet still carried on the bed of pins. Prior to the lamination station, the web passes over a gamma gage (not shown) that provides a rough measure of the mass per unit area of the web. This measurement can be used as feedback to control the upstream carding and cross-lapping operations. The web is stable enough at this stage to be accumulated in an accumulator **90** between the needling and lamination stations. As known in the art, accumulator **90** is followed by a spreading roll (not shown) that spreads and centers the web prior to entering the next process. Prior to lamination, the web may also pass through a coating station (not shown) in which a binder is applied to enhance lamination. In lamination station **92**, the web first passes by one or more infrared heaters **94** that preheat the fibers and/or carrier sheet from the side opposite the loops. In products relying on bicomponent fibers for bonding, heaters **94** preheat and soften the sheaths of the bicomponent fibers. In one example, the heater length and line speed are such that the web spends about four seconds in front of the heaters. Just downstream of the heaters is a web temperature sensor (not shown) that provides feedback to the heater control to maintain a desired web exit temperature. For lamination, the heated web is trained about a hot can **96** against which four idler card cloth-covered rolls **98** of five inch (13 centimeters) solid diameter (excluding the card cloth), and a driven, rubber, card cloth-covered roll **100** of 18 inch (46 centimeters) solid diameter, rotate under controlled pressure. The pins of the card cloth rolls **98**,**100** thus press the web against the surface of hot can **96** at discrete pressure points, thus bonding the fibers at discrete locations without crushing other fibers, generally between the bond points, that remain exposed and open for engagement by hooks. For many materials, the bonding pressure between the card cloth rolls and the hot can is quite low, in the range of 1-10 pounds per square inch (70-700 grams per square centimeter) or less. The hot can **96** can have a compliant outer surface, or be in the form of a belt. As an alternative to roller nips, a flatbed fabric laminator (not shown) can be employed to apply a controlled lamination pressure for a considerable dwell time. Such flatbed laminators are available from Glenro Inc. in Paterson, N.J. In some applications, the finished loop product is passed through a cooler (not shown) prior to embossing.

The pins extending from card cloth-covered rolls **98**,**100** are arranged in an array of rows and columns, with a pin density of about 200 and 350 pins per square inch (31 to 54 pins per square centimeter) in a flat state, preferred to be between about 250 to 300 pins per square inch (39 to 47 pins per square centimeter). The pins are each about 0.020 inch (0.5 millimeter) in diameter, and are preferably straight to withstand the pressure required to laminate the web. The pins extend from a backing about 0.25 inch (6.4 millimeters) in thickness. The backing is of two layers of about equal thickness, the lower layer being of fibrous webbing and the upper layer being of rubber. The pins extend about 0.25 inch (6.4 millimeters) from the rubber side of the backing. Because of the curvature of the card cloth rolls, the effective density of the pin tips, where lamination occurs, is lower than that of the pins with the card cloth in a flat state. A flat state pin density of 200 to 350 pins per square inch (31 to 54 pins per square centimeter) equates to an effective pin density of only 22 to 38 pins per square centimeter on idler rolls **98**, and 28 to 49 pins per square centimeter on driven rubber roll **100**. In most cases, it is preferable that the pins not penetrate the carrier sheet during bonding, but that each pin provide sufficient support to form a robust bond point between the fibers. In a non-continuous production method, such as for preparing discrete patches of loop material, a piece of carrier sheet **14** and a section of fiber mat **12** may be layered upon a single card cloth, such as are employed for carding webs, for needling and subsequent bonding, prior to removal from the card cloth.

FIG. **3** is an enlarged view of the nip between hot can **96** and one of the card cloth rolls. As discussed above, due to the curvature of the card cloth rolls, their pins **102** splay outward, such that the effective pin density at the hot can is lower than that of the card cloth in a planar state. The pins contact the carrier sheet (or its remnants, depending on needling density) and fuse underlying fibers to each other and/or to material of the carrier sheet, forming a rather solid mass **42** of fused material in the vicinity of the pin tip, and a penumbral area of fused but distinct fibers surrounding each pin. The laminating parameters can be varied to cause these penumbral, partially fused areas to be overlapped if desired, creating a very strong, dimensionally stable web of fused fibers across the non-working side of the loop product that is still sufficiently flexible for many uses. Alternatively, the web can be laminated such that the penumbral areas are distinct and separate, creating a looser web. For most applications the fibers should not be continuously fused into a solid mass across the back of the product, in order to retain a good hand and working flexibility. The number of discrete fused areas per unit area of the bonded web is such that staple fibers with portions extending through holes to form engageable loops **40** that have other portions, such as their ends, secured in one or more of such fused areas **42**, such that the fused areas are primarily involved in anchoring the loop fibers against pullout from hook loads. Whether the welds are discrete points or an interconnected grid, this further secures the fibers, helping to strengthen the loop structures **48**. The laminating occurs while the loop structures **48** are safely disposed between pins **102**, such that no pressure is applied to crush the loops during bonding. Protecting the loop structures during lamination significantly improves the performance of the material as a touch fastener, as the loop structures remain extended from the base for hook engagement.

If desired, a backing sheet (not shown) can be introduced between the hot can and the needled web, such that the backing sheet is laminated over the back surface of the loop product while the fibers are bonded under pressure from the pins of apron **22**.

Referring back to FIG. **1**, from lamination station **92** the laminated web moves through another accumulator **90** to an embossing station **104**, where a desired pattern of locally raised regions is embossed into the web between two counter-rotating embossing rolls. In some cases, the web may move directly from the laminator to the embossing station, without accumulation, so as to take advantage of any latent temperature increase caused by lamination. The loop side of the bonded loop product is embossed with a desired embossing pattern prior to spooling. In this example the loop product is passed through a nip between a driven embossing roll **54** and a backup roll **56**. The embossing roll **54** has a pattern of raised areas that permanently crush the loop formations against the carrier sheet, and may even melt a proportion of the fibers in those areas. Embossing may be employed simply to enhance the texture or aesthetic appeal of the final product. In some cases, roll **56** has a pattern of raised areas that mesh with dimples in roll **54**, such that embossing results in a pattern of raised hills or convex regions on the loop side, with corresponding concave regions **45** (FIG. **7**B) on the non-working side of the product, such that the embossed product has a greater effective thickness than the pre-embossed product. Additionally, as shown in FIG. **7**B, embossing presents the loop structures **48** or otherwise engageable fiber portions at different angles to a mating field of hooks, for better engagement. More details of a suitable embossing pattern are discussed below with respect to FIGS. **7** and **7**A.

The embossed web then moves through a third accumulator **90**, past a metal detector **106** that checks for any broken needles or other metal debris, and then is slit and spooled for storage or shipment. During slitting, edges may be trimmed and removed, as can any undesired carrier sheet overlap region necessitated by using multiple parallel strips of carrier sheet.

We have found that, using the process described above, a useful loop product may be formed with relatively little fiber **12**. In one example, mat **10** has a basis weight of only about 1.0 osy (33 grams per square meter). Fibers **12** are drawn and crimped polyester fibers, 3 to 6 denier, of about a four-inch (10 centimeters) staple length, mixed with crimped bicomponent polyester fibers of 4 denier and about two-inch (5 centimeters) staple length. The ratio of fibers may be, for example, 80 percent solid polyester fiber to 20 percent bicomponent fiber. In other embodiments, the fibers may include 15 to 30 percent bicomponent fibers. The preferred ratio will depend on the composition of the fibers and the processing conditions. Generally, too little bicomponent fiber may compromise loop anchoring, due to insufficient fusing of the fibers, while too much bicomponent fiber will tend to increase cost and may result in a stiff product and/or one in which some of the loops are adhered to each other. The bicomponent fibers are core/sheath drawn fibers consisting of a polyester core and a copolyester sheath having a softening temperature of about 110 degrees Celsius, and are employed to bind the solid polyester fibers to each other and the carrier.

In this example, both types of fibers are of round cross-section and are crimped at about 7.5 crimps per inch (3 crimps per centimeter). Suitable polyester fibers are available from INVISTA of Wichita, Kans., (www.invista.com) under the designation Type 291. Suitable bicomponent fibers are available from INVISTA under the designation Type 254. As an alternative to round cross-section fibers, fibers of other cross-sections having angular surface aspects, e.g. fibers of pentagon or pentalobal cross-section, can enhance knot formation during needling.

Loop fibers with tenacity values of at least 2.8 grams per denier have been found to provide good closure performance, and fibers with a tenacity of at least 5 or more grams per denier (preferably even 8 or more grams per denier) are even more preferred in many instances. In general terms for a loop-limited closure, the higher the loop tenacity, the stronger the closure. The polyester fibers of mat **10** are in a drawn, molecular oriented state, having been drawn with a draw ratio of at least 2:1 (i.e., to at least twice their original length) under cooling conditions that enable molecular orientation to occur, to provide a fiber tenacity of about 4.8 grams per denier.

The loop fiber denier should be chosen with the hook size in mind, with lower denier fibers typically selected for use with smaller hooks. For low-cycle applications for use with larger hooks (and therefore preferably larger diameter loop fibers), fibers of lower tenacity or larger diameter may be employed.

For many applications, particularly products where the hook and loop components will be engaged and disengaged more than once ("cycled"), it is desirable that the loops have relatively high strength so that they do not break or tear when the fastener product is disengaged. Loop breakage causes the loop material to have a "fuzzy," damaged appearance, and widespread breakage can deleteriously effect re-engagement of the fastener.

Loop strength is directly proportional to fiber strength, which is the product of tenacity and denier. Fibers having a fiber strength of at least 6 grams, for example at least 10 grams, provide sufficient loop strength for many applications. Where higher loop strength is required, the fiber strength may be higher, e.g., at least 15 grams. Strengths in these ranges may be obtained by using fibers having a tenacity of about 2 to 7 grams/denier and a denier of about 1.5 to 5, e.g., 2 to 4. For example, a fiber having a tenacity of about 4 grams/denier and a denier of about 3 will have a fiber strength of about 12 grams.

Other factors that affect engagement strength and cycling are the geometry of the loop structures, the resistance of the loop structures to pull-out, and the density and uniformity of the loop structures over the surface area of the loop product. The first two of these factors are discussed above. The density and uniformity of the loop structures is determined in part by the coverage of the fibers on the carrier sheet. In other words, the coverage will affect how many of the needle penetrations will result in hook-engageable loop structures. Fiber coverage is indicative of the length of fiber per unit area of the carrier sheet, and is calculated as follows:

$$\text{Fiber coverage (in meters per square meter)}=\text{Basis Weight/Denier}\times 9000$$

Thus, in order to obtain a relatively high fiber coverage at a low basis weight, e.g., less than 33 gsm, it is desirable to use relatively low denier (i.e., fine) fibers. However, the use of low denier fibers will require that the fibers have a higher tenacity to obtain a given fiber strength, as discussed above. Higher tenacity fibers are generally more expensive than lower tenacity fibers, so the desired strength, cost and weight characteristics of the product must be balanced to determine the appropriate basis weight, fiber tenacity and denier for a particular application. It is generally preferred that the fiber layer of the loop product have a calculated fiber coverage of at least 50,000, preferably at least 90,000, and more preferably at least 100,000.

To produce loop materials having a good balance of low cost, light weight and good performance, it is generally preferred that the basis weight be less than 70 gsm, e.g., 33 to 67 gsm, and the coverage be about 50,000 to 200,000.

Various synthetic or natural fibers may be employed. In some applications, wool and cotton may provide sufficient fiber strength. Presently, thermoplastic staple fibers which have substantial tenacity are preferred for making thin, low-cost loop product that has good closure performance when paired with very small molded hooks. For example, polyolefins (e.g., polypropylene or polyethylene), polyesters (e.g., polyethylene terephthalate), polyamides (e.g., nylon), acrylics and mixtures, alloys, copolymers and co-extrusions thereof are suitable. Polyester is presently preferred. Fibers having high tenacity and high melt temperature may be mixed with fibers of a lower melt temperature resin. For a product having some electrical conductivity, a small percentage of metal fibers may be added. For instance, loop products of up to about 5 to 10 percent fine metal fiber, for example, may be advantageously employed for grounding or other electrical applications.

The paper carrier sheet **14** may be pre-pasted with an adhesive on the fiber side to help bond the fibers and/or a backing layer to the paper.

Still referring to FIG. **1**, in some cases a wire screen is used in place of both the bed of pins or bristles **20** and driven support belt **22**, for an analogous needling process. The wires define openings through which the needle passes as it draws fibers **12** through the carrier sheet **14**. Suitable screens can be made from materials including bronze, copper, brass, and stainless steel. We have found that screens made of brass wire with a nominal diameter of between about 0.02 and 0.03 inch (0.5 and 0.8 millimeter) or, more preferably, between about 0.023 and 0.028 inch (0.6 and 0.7 millimeter), are resilient without being too stiff. Screens having openings with a nominal width of between about 0.05 and 0.2 inch (1.3 and 5.1 millimeter) or, more preferably, between about 0.06 and 0.1 inch (1.5 and 2.5 millimeter) are appropriate for this purpose. Such screens are available from McMaster-Carr Supply Co. of Elmhurst, Ill. under the designation 9223T41.

FIG. **4** is an enlarged view of a loop structure **48** containing multiple loops **40** extending from a common trunk **43** through a hole in paper **14**, as formed by the above-described method. As shown, loops **40** stand proud of the underlying paper, available for engagement with a mating hook product, due at least in part to the vertical stiffness of trunk **43** of each formation, which is provided by the anchoring of the fibers to each other and the paper. This vertical stiffness acts to resist permanent crushing or flattening of the loop structures, which can occur when the loop material is spooled or when the finished product to which the loop material is later joined is compressed for packaging. Stiff papers do not tend to form the lip shown protruding about the trunk **43** of the formation. Resiliency of the trunk **43**, especially at its juncture with the base, enables structures **48** that have been "toppled" by heavy crush loads to right themselves when the load is removed. The various loops **40** of formation **48** extend to different heights from the paper, which is also believed to promote fastener performance. Because each formation **48** is formed at a site of a penetration of paper **14** during needling, the density and location of the individual structures are very controllable. Preferably, there is sufficient distance between adjacent structures so as to enable good penetration of the field of formations by a field of mating male fastener elements (not shown). Each of the loops **40** is of a staple fiber whose ends are disposed on the opposite side of the carrier sheet, such that the loops are each structurally capable of hook engagement. One of the loops **40** in this view is shown as being of a bicomponent fiber **41**. After laminating, the paper and fibers become permanently bonded together at discrete points **42** corresponding to the distal ends of pins **20**.

Because of the relatively low amount of fibers remaining in the mat, together with the thinness of the carrier sheet and any applied backing layer, mat **108** can have a thickness "t_m" of only about 0.008 inch (0.2 millimeters) or less, preferably less than about 0.005 inch, and even as low as about 0.001 inch

(0.025 millimeter) in some cases. The carrier may **14** have a thickness of less than about 0.002 inch (0.05 millimeter), preferably less than about 0.001 inch (0.025 millimeter). The finished loop product **30** has an overall thickness "T" of less than about 0.15 inch (3.7 millimeters), preferably less than about 0.1 inch (2.5 millimeters). The overall weight of the loop fastener product, including carrier sheet, fibers and fused binder (an optional component, discussed below), is preferably less than about 5 ounces per square yard (167 grams per square meter). For some applications, the overall weight is less than about 2 ounces per square yard (67 grams per square meter).

FIG. **4**A is an enlarged photograph of a loop product formed by needling fibers through a film with fork needles. The view is taken toward a folded edge of the product, so as to spread out the loop structures for increased visibility. Five of the loop structures shown in the photograph have been marked with an 'X'. The surface of the film is clearly visible between the loop structures, each of which contains many individual loops emanating from a common trunk, as shown in FIG. **4**B, an enlarged view of a single one of the loop structures. In FIG. **4**B, light is clearly seen reflected at the base of the loop structure from film that has been raised about the hole during piercing. An outline of the raised portion of film is shown on the photograph.

Needling papers of rather high notch sensitivity or tendency to tear can create loop structures of the sort shown in FIG. **4**C. In this case, the paper about the hole created by a needle doesn't tend to create the 'turtleneck' effect as in FIG. **4**, with the result that the fibers passing through the paper may be not as securely supported against crushing. Well-supported loop trees are more able to resist crushing, such as from spooling of the loop material, than less-supported bush structures.

Referring next to FIG. **5**, in an alternative lamination step a powdered binder **46** is deposited over the fiber side of the needle-punched paper and then fused to the paper by roll **28** or a flatbed laminator. For example, a polyethylene powder with a nominal particle size of about 20 microns can be sprinkled over the fiber-layered paper in a distribution of only about 0.5 ounces per square yard (17 grams per square meter). Such powder is available in either a ground, irregular shape or a generally spherical form from Equistar Chemicals LP in Houston, Tex.. Preferably, the powder form and particle size are selected to enable the powder to sift into interstices between the fibers and contact the underlying paper. It is also preferable, for many applications, that the powder be of a material with a lower melt temperature than the loop fibers, such that during bonding the fibers remain generally intact and the powder binder fuses to either the fibers or the carrier web. In either case, the powder acts to mechanically bind the fibers to the paper in the vicinity of the supporting pins and anchor the loop structures. In sufficient quantity, powder **46** can also form at least a partial backing in the finished loop product, for permanently bonding the loop material onto a compatible substrate. Other powder materials, such as polypropylene or an EVA resin, may also be employed for this purpose, with appropriate carrier web materials, as can mixtures of different powders.

Referring back to FIG. **1**, in some cases the needling parameters (e.g., needle size, needling density) can be selected to cause the carrier web **14** to be practically disintegrated during needling. While this is undesirable for some applications, we have found that such a structure is advantageous for other uses. FIG. **6** illustrates a resulting structure, in which the fibers **12** themselves form practically the only connectivity within the needled sheet. The paper itself remains in the form of discrete portions **69** separated by cracks **67** extending between adjacent loop trunks **43**. This structure is sufficiently dimensionally stable to be laminated to a stretchable backing film, such as a polypropylene or polyethylene film available from Tredegar Film Products in Richmond, Va.. During lamination, the discrete segments **66** of carrier paper may bond to the stretchable backing, further anchoring the bases of the loop structures while permitting the final loop product to be elastically stretchable within its plane.

A pre-printed paper may be employed as the carrier web to provide graphic images visible from one or both sides of the finished product. The small bonding spots and the low density of fiber remaining in the mat generally do not significantly detract from the visibility of the image. This can be advantageous, for example, for loop materials to be used on children's products, such as disposable diapers, or in packaging.

FIG. **7** shows a finished loop product, as seen from the loop side, embossed with a honeycomb pattern **58**. In this example, graphic images **130** printed on the back side of the carrier (in this case, a film) are clearly visible through the loops. Various other embossing patterns include, as examples, a grid of intersecting lines forming squares or diamonds, or a pattern that crushes the loop formations other than in discrete regions of a desired shape, such as round pads of loops. The embossing pattern may also crush the loops to form a desired image, or text, on the loop material. As shown in FIG. **7**A, each cell of the embossing pattern is a closed hexagon and contains multiple discrete loop structures. The width 'W' between opposite sides of the open area of the cell is about 6.5 millimeters, while the thickness 't' of the wall of the cell is about 0.8 millimeter.

Referring to FIG. **8**, in one method of forming a product with only discrete regions of loop the fiber-covered carrier web is needled only in desired regions, leaving other areas of the web unpenetrated. The fibers in the non-needled regions remain generally loose and are readily removed from the carrier web, such as by vacuum **110**. Removed fibers are readily re-carded and thus recycled. The needled web is then optionally laminated to a backing **26**, fusing to the carrier sheet in the fiber-covered and needled regions as well as in the fiber-free regions. Alternatively, the fibers are fused to each other and/or the carrier sheet under pressure applied by hot can **28**, without an added backing layer. The laminate product is then spooled for later use.

In the alternative bonding process illustrated in FIG. **9**, discrete patches of backing **26** are applied to cover the needled and fiber-bearing regions of carrier web **14**, leaving the remaining regions of the carrier web uncovered and unlaminated. Each backing patch **26** is bonded in place by pressure from roller **112** to cover the fibers remaining on the back surface of the carrier web. Fluid impermeable patches **26** can be employed to seal the needled holes, thereby creating a fluid-impermeable finished product of particularly low weight and nominal thickness. In some cases, paper backing patches **26** are pre-coated with an adhesive that adheres the backing to the carrier paper and bonds the fibers. Patches **26** can be delivered to carrier **14** on a circulating conveyor belt **114** in a labeling process, as shown.

If the needled regions of the loop product are covered with a backing material **26** selected to be liquid impermeable, then the entire loop product can be formed to provide a barrier to liquids. If fibers **12** are selected to be absorbent, such as of cotton or cellulosic acetate, then the final loop product can be employed to wick liquids into the mat via the exposed loops **40**.

The above-described processes enable the cost-effective production of high volumes of loop-covered paper materials with good fastening characteristics. They can also be employed to produce loop materials in which the materials of the loops, substrate and optional backing are individually selected for optimal qualities. For example, the loop fiber material can be selected to have high tenacity for fastening strength, while the paper substrate and/or backing material can be selected to be readily bonded to other materials without harming the loop fibers.

The carrier web can be a solid or a very porous sheet of paper, and can be, for example, very soft paper such tissue paper (bathroom or facial tissue, for example), stronger papers such as Kraft paper (made by adding sodium sulfate to the soda process in paper making), disposable paper towels, typing paper, newsprint stock, or "construction" paper. The paper carrier web may be pre-pasted with an adhesive on the fiber side to help bond the fibers and/or a backing layer to the paper. Heavier papers may require larger needles for piercing, which may be arranged in a lower needle density on the needle board to reduce needling loads. The needles may also need to be checked more frequently for wear caused by abrasion from the paper.

Biodegradable loop products can be made from paper into which biodegradable fibers are needled. Such fibers that have sufficient tenacity to form loops include, for example, polyvinyl alcohol (PVA) and polylactic acid fibers.

Polymer backing layers or binders may be selected from among suitable polyethylenes, polyesters, EVA, polypropylenes, and their co-polymers. Paper, fabric or even metal may be used. The binder may be applied in liquid or powder form, and may even be pre-coated on the fiber side of the carrier web before the fibers are applied. In many cases, a separate binder or backing layer is not required, such as for low cycle applications.

FIG. **10** shows a loop product **300** consisting essentially of a sheet of paper **302** and fibers that have been needled through the paper from back side **304**, as described above, to form discrete loop structures **48** on the front side. The needled, fiber-punched paper is laminated with card cloth as discussed above with respect to FIG. **1**, such that fibers on back side **304** are bonded to each other at discrete points, without forming an overly stiff backing. We have found that some types of paper remain quite dimensionally stable and cohesive through needling, such that the paper substrate may, in many cases, provide a surface suitable for bonding to film or other substrates, such as with adhesives. The bonded web of fibers remaining on the back can be heated to form an adhesive for bonding the paper to another material, such as polyethylene film, or a separate adhesive may be applied.

In one example, the product **300** of FIG. **10** is a towel for general purpose cleaning, and is formed from a standard paper towel into which PVA fibers have been needled. The resulting product is less susceptible to disintegration when wet than the un-needled paper towel, as the PVA fibers tend to provide dimensional stability as the paper substrate loses strength when wet. Thus, the product is more capable of performing cleaning functions in a wet state, but remains disposable and biodegradable.

In another example, the product **300** of FIG. **10** is a scrubbing sheet material, consisting essentially of a paper substrate **302** into which emery fibers have been needled according to the methods discussed above. The paper provides a carrier sheet for the emery fibers during manufacture, such that less such expensive fibers are required than in scrubbing products formed by needling a thick batt of such fibers. Furthermore, the surface structure of discrete, spaced apart loop structures is considered to be particularly suitable for scrubbing.

In another example, the product **300** of FIG. **10** is a backing material for an abrasive disk, which may be formed by bonding abrasive particles (not shown) to the back side **304** of the product, such that loop structures **48** extend from the side opposite the abrasive particles and can serve to releasably attach the abrasive disk or sheet to a holder, such as an electric sander. Referring also to FIG. **13**, a sanding disk or sandpaper **320** has an array of engageable loop structures **48** formed by needling polymer fibers through a sheet **14** of paper, leaving a thin layer of fibers on the opposite side of the paper, and then bonding a field of abrasive particles **322**, such as silica or other hard material, on the other side.

In another example, the product **300** of FIG. **10** is an abrasive sheet, consisting essentially of steel wool fibers or other hard fibers needled through paper or another carrier. As in the previous examples, employing the paper substrate to carry the loose fibers prior to and during needling enables the use of fewer expensive fibers, resulting in a cost effective product with consistently formed loop structures **48** spaced about on the surface of the product where their properties are most needed. Such constructions also result in usefully thin and flexible products. Referring also to FIG. **14**, a sanding material **324** has a paper substrate **14** through which staple steel wool fibers have been needled to form loop structures **48**. Steel wool fibers **326** remaining on the opposite surface of the paper form an abrasive working surface **328**, while the loop structures releasably secure material **324** to a carrier.

In another example, the product **300** of FIG. **10** is a fastener product, with loop structures **48** configured for hook engagement to form a touch fastener, using the loop fiber materials discussed above. Various applications of such a paper-based loop material are envisioned. For example, in FIG. **11** a piece of unbleached, uncoated paper has been needled with polyethylene stable fibers and laminated to bond the fibers as discussed above. A pleated paper core **308** is then sandwiched between the resulting sheet-form loop-covered paper product **300** and another sheet **310** of paper, to form a corrugated cardboard **312**. Such cardboard can be formed into boxes, displays or other structures, with loop product **300** covering an exposed surface for mounting hook-bearing papers or products.

In another example shown in FIG. **12**, multiple sheets of loop-bearing paper **300** are bound together to form a photo album or scrapbook **314**, in which hook-backed photos **316** or other memorabilia are releasably secured by engagement of their hooks with the loop structures of paper **300**. For this application, the fibers remaining on the back side of the paper may provide sufficient fastening performance to mount such photos on the opposite sides of the paper, as well. Hook-backed photo paper and its method of manufacture are disclosed in a PCT application published Mar. 4, 2004, as WO04/017781. Other uses and constructions of loop-covered paper products are disclosed in pending U.S. application Ser. No. 10/657,507, the entire contents of which are hereby incorporated by reference.

The carrier sheets in the specific examples discussed above may be materials other than paper.

Paper substrates may be pre-printed with desired graphics, either on one or both sides, prior to needling.

A number of embodiments of the invention have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. Accordingly, other embodiments are within the scope of the following claims.

What is claimed is:

1. A method of making a sheet-form loop fastener product, the method comprising

placing a layer of staple fibers against a first side of a flexible paper substrate;

needling fibers of the layer through the paper substrate by piercing the substrate with needles that drag portions of the fibers through holes formed in the paper substrate during needling, forming loops of the fibers extending from the holes on a second side of the paper substrate;

selecting needling parameters so that the loops have a size and structure selected to engage a field of corresponding male fastener elements; and

anchoring fibers forming the loops sufficiently to resist pull-out loads caused by releasable engagement with the male fastener elements.

2. The method of claim 1 wherein the fibers include bicomponent fibers having a core of one material and a sheath of another material, and wherein anchoring the fibers comprises melting material of the sheaths of the bicomponent fibers to bind fibers together.

3. The method of claim 1 wherein needling fibers of the layer through the paper substrate and anchoring fibers forming the loops forms loops sized and constructed to be releasably engageable by a field of hooks for hook-and-loop fastening.

4. The method of claim 1 wherein the staple fibers are disposed on the substrate in a layer of a total fiber weight of less than about 2 ounces per square yard (67 grams per square meter).

5. The method of claim 4 wherein the staple fibers are disposed on the substrate in a layer of a total fiber weight of no more than about one ounce per square yard (34 grams per square meter).

6. The method of claim 1 wherein the staple fibers are disposed on the substrate in a carded, unbonded state.

7. The method of claim 1 further comprising, prior to disposing the fibers on the substrate, carding and cross-lapping the fibers.

8. The method of claim 1 wherein the loop product has an overall weight of less than about 5 ounces per square yard (167 grams per square meter).

9. The method of claim 1 wherein anchoring occurs subsequent to needling.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 7,465,366 B2
APPLICATION NO. : 11/104166
DATED : December 16, 2008
INVENTOR(S) : George A. Provost

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Title Page item 73 column 1 (Assignee), line 1:
delete "Velero" and replace with --Velcro--.

Title Page item 73 column 1 (Assignee), line 1:
delete "Curcao" and replace with --Curacao--.

Signed and Sealed this

Third Day of March, 2009

John Doll

JOHN DOLL
Acting Director of the United States Patent and Trademark Office